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# PESTICIDE TRANSPORT AND RUNOFF MODEL FOR AGRICULTURAL LANDS

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N.H. Crawford and A.S. Donigian, Jr.

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The development and testing of a mathematical model to simulate the loss of pesticides from agricultural lands is presented. The Pesticide Transport and Runoff (PTR) Model is composed of submodels concerned with hydrology, sediment loss, pesticide-soil interaction, and pesticide attenuation functions. The Model 'piggybacks' the applied pesticide onto the movement of water through the soil profile and the loss of water and sediment from the land surface. The pesticide-soil interaction is based on the Freundlich adsorption-desorption isotherm. Attenuation functions of volatilization and degradation are provided but were not tested due to lack of data.

Comparison of simulated and recorded runoff and sediment loss showed considerable agreement. Simulated pesticide loss agreed reasonably well with recorded values for those pesticides completely adsorbed on sediment particles. The Freundlich adsorption model did not accurately predict the division between the adsorbed and dissolved states for those pesticides which are transported by runoff and sediment loss. Recommendations for future work include further calibration and testing of the PTR Model, and additional development on the pesticide adsorption and attenuation functions. The regulation of pesticide releases to the environment ~~are~~ is explored as possible eventual use~~s~~ of the PTR Model. (EPA)

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# PESTICIDE TRANSPORT AND RUNOFF MODEL FOR AGRICULTURAL LANDS

By

Norman H. Crawford
Principal Investigator

and

Anthony S. Donigian, Jr.
Project Manager

Contract No. 68-01-0887
Program Element 1BB039

Project Officer

Dr. George W. Bailey
Southeast Environmental Research Laboratory
Environmental Protection Agency
Athens, Georgia 30601

Prepared for

OFFICE OF RESEARCH AND DEVELOPMENT
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# ABSTRACT

The development and testing of a mathematical model to simulate the loss of pesticides from agricultural lands is presented. The Pesticide Transport and Runoff (PTR) Model is composed of submodels concerned with hydrology, sediment loss, pesticide-soil interaction, and pesticide attenuation functions. The Model 'piggybacks' the applied pesticide onto the movement of water through the soil profile and the loss of water and sediment from the land surface. The pesticide-soil interaction is based on the Freundlich adsorption-desorption isotherm, which provides the division between the adsorbed and dissolved states of the pesticide. Attenuation functions of volatilization and degradation are provided but were not tested due to lack of data.

An extensive sampling and data-gathering program at the EPA Southeast Environmental Research Laboratory (Athens, Georgia) provided observed data on pesticide loss from experimental plots in the Southern Piedmont. Comparison of simulated and recorded runoff and sediment loss showed considerable agreement. Simulated pesticide loss agreed reasonably well with recorded values for those pesticides completely adsorbed on sediment particles. The Freundlich adsorption model did not accurately predict the division between the adsorbed and dissolved states for those pesticides which are transported by runoff and sediment loss. Recommendations for future work include further calibration and testing of the PTR Model, and additional refinement of the pesticide adsorption/desorption and attenuation functions. The regulation of pesticide releases to the environment are explored as possible eventual uses of the PTR Model.

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# SECTION I

## CONCLUSIONS

1. The PTR Model was developed to simulate the transport of pesticides in solution and on sediment. The Model uses physically - based submodels to calculate runoff volumes and sediment concentrations. Initial model tests show good results for transport of pesticides on sediment and fair-to-good results for transport in solution.

2. Surface runoff from agricultural lands in the Southern Piedmont can be simulated with reasonable accuracy with the PTR Model. The hydrologic submodel has been used extensively in other studies, and past experience indicates that similar simulation accuracy for runoff volumes can be expected in other geographical regions.

3. Simulation of monthly sediment loss agrees adequately with recorded volumes; however, sediment concentrations during storm events vary somewhat from the observed values. The general nature of the sediment submodel shows promise of applicability to other regions, although experience is limited at the present time.

4. The PTR Model has demonstrated the capability of providing reasonable estimates of surface runoff and sediment loss from agricultural watersheds in the Southern Piedmont. These routes are the major modes of transport of pesticides and other non-point source pollutants to waterbodies. Consequently, further refinement of the pesticide functions (adsorption/desorption, volatilization, and degradation) will upgrade the capability of the model to predict the pesticide input to waterbodies from surface washoff. Moreover, the PTR Model can provide the basis for the simulation of other non-point source pollutants (nutrients, fertilizers, etc.), and thus estimate the water quality of surface runoff from agricultural lands.

5. The loss of paraquat from the experimental watershed is simulated reasonably well by assuming complete adsorption onto sediment particles. Pesticides with a similar attraction to soil particles would likely produce similar results.

6. The single-valued (reversible) Freundlich adsorption isotherm appears to be inadequate in simulating the division between adsorbed and dissolved phases of diphenamid in runoff from the watersheds. This was also evidenced by the inability to simulate the observed vertical movement of the pesticides.

7. The observed variations in pesticide concentrations during runoff events appears to be of little consequence in predicting total pesticide loss; total mass movement of pesticide (grams/minute) past the gage during a storm event is a more valid comparison between simulated and observed pesticide loss.

8. Although simulated and recorded pesticide amounts remaining on the watersheds agreed reasonably well, concentrations within the soil profile were in error. The assumed depths of the soil zones is largely responsible for this discrepancy because the pesticide concentration is dependent on the total mass of soil in the zone.

# SECTION II

# RECOMMENDATIONS

From the results and conclusions of the present research effort, and considering future uses of tne PTR Model in pesticide regulation, the following recommendations are presented:

1. Continuous simulation of pesticide transport, as opposed to static steady-state investigations, has been shown to be a valid methodology for performing a materials balance of pesticides applied to agricultural lands. The dynamic nature of continuous simulation allows the full accounting of: (a) pesticides remaining on the land surface, (b) pesticide concentrations and volume lost during storm events, and (c) accumulated amounts of pesticide lost to the aquatic ecosystem during a growing season. Consequently this approach to the investigation of pesticide transport warrants further refinement.

2. An understanding of the mechanisms of surface runoff and sediment loss is paramount to the study of the importance of non-point source pollutants on water quality. The PTR Model has demonstrated the capability of representing these mechanisms. Consequently, the coupling of the PTR Model with additional pollutant attenuation, adsorption, and degradation functions could provide the structure for modeling the transport of plant nutrients, fertilizers, animal wastes, and other non-point source pollutants. The effects of silvicultural and agricultural management techniques on water quality could be evaluated through the PTR Model by their effect on the transport mechanisms of the non-point source pollutants. Development of such submodels needs to be undertaken in order to realize the full potential of the Model as a management tool.

3. For further refinement of the existing PTR Model, future research needs to be concerned with:
   a. additional testing and calibration of the hydrologic model to more accurately evaluate model algorithms and land surface parameters.
   b. calibration and possible refinement of the sediment loss

model to better reproduce recorded sediment concentrations and to gain experience with the sensitivity of the sediment loss parameters.

c. refinement and testing of the adsorption-desorption model to better determine the division between the adsorbed and dissolved phases of pesticides which are transported on both sediment and water. The inclusion of a nonsingle-valued adsorption-desorption model warrants further investigation. These refinements are critical to the reliable prediction of pesticide lost in water and on sediment during storm events.

d. additional development and testing of the volatilization and degradation models on actual field data, so that an accurate pesticide materials balance can be performed. The effects of environmental factors on these mechanisms needs to be investigated.

4. To determine the general applicability of the PTR Model, the following tasks are recommended:

a. Calibration and testing of the Model for runoff and sediment loss on watersheds in various regions of the country. This would allow investigation of changes in parameter values with varying soil and climatic characteristics, and would demonstrate the behavior of the Model under varying conditions.

b. Evaluation of model performance on watersheds ranging from 20 to 200 hectaries in order to determine required improvements in the Model for larger watersheds. This would provide insight into the effects of channel processes on runoff and sediment loss, and demonstrate the efficacy of existing model algorithms to simulate the hydrologic and erosion processes.

5. If the PTR Model is to be considered as a tool for regulating the release of pesticides, the following areas need to be investigated:

a. determination and definition of control-size watersheds in various regions of the country which would be most amenable to pesticide release regulations.

b. classification and grouping of pesticides according to toxicity, transport, and persistence characteristics

c. establishment of maximum seasonal releases of pesticides within each classification which would not inflict serious consequences on man or the aquatic ecosyste. The fractions of applied pesticides which reach waterbodies could then be evaluated by the PTR Model and provide a basis for regulating pesticide releases.

# SECTION III

# INTRODUCTION

In 1962, the publication of Rachel Carson's "Silent Spring" exposed a problem which had been smoldering for a number of years within the confines of the academic and scientific communities -- the indiscriminate use of toxic pesticides in the environment. The vituperative dialogue which resulted between the ecologically and agriculturally minded sectors of society has since gradually diminished. At the present time, it appears that the pesticide situation has attained a more rational and more productive level. Enforcement of pesticide registration has been expanded at both the state and federal levels. Certain persistent and extremely toxic pesticides have been banned except in emergencies involving the public health. Studies on the transport, attenuation, accumulation and toxic effects of pesticides have proliferated and are continuing by various governmental agencies. To adequately understand problems posed by pesticide usage, it is necessary to comprehend the arguments put forward by both sides of the conflict. In this way, the requisite data and research can be determined and instigated so that a methodology can be developed to equitably regulate pesticide releases to the environment. Such a regulatory system must necessarily consider the values of all sectors of society concerned with the pesticide problem.

## THE PESTICIDE PROBLEM

Pesticide is a general term for all forms of insecticides, herbicides, fungicides, fumigants, nematocides, algacides, rodenticides, etc. A pesticide is often described as a substance used to control objectionable forms of life. Ecologists prefer to use the term "biocide", denoting the destruction of life forms. Many governmental agencies will employ the term "economic poison" to stress the monetary gains obtainable. In any case, the total production of these chemicals in 1971 amounted to 600,000 tonnes [1] involving nearly 1,000 registered chemicals produced in over 32,000 formulations However, of the 1971 production, 65% (385,000 tonnes) can be attributed to only 24 different pesticidal chemicals [1], i.e. a relatively small number of pesticides is produced in large quantities.

In 1939, the discovery of the insecticidal properties of DDT was hailed as a great advance in the science of public health. Swiss chemist Paul Muller was awarded the Nobel Prize in 1948 for his part in the discovery. With the advent of low-cost production methods, the production of DDT climbed steadily in the post World War II period. This fact initiated intensive research into chemicals with structural properties similar to DDT, known as the chlorinated hydrocarbons. It was this group of pesticides which absorbed the brunt of the attack by Rachel Carson in Silent Spring. The persistence and biomagnification of these pesticides in the environment are the main factors which have led to the decline in their use. The detection of DDT in remote regions of the globe, and the discovery that marine fish are almost universally contaminated with DDT residues [3] are testimony to these problems of persistence and biomagnification. In some cases, pesticidal chemicals will lodge and accumulate in fat tissues. Since lower animals serve as food for the higher animals, the chemical content of the fat tends to increase in concentration as one moves up the food chain. The discovery of DDT in mother's milk [4] indicates that man, the finale of the food chain, is not immune to this problem.

There is no need to cite the numerous accidents and catastrophies which have resulted due to pesticidal contamination of the environment. This has been done quite eloquently elsewhere [4, 5, 6]. The problem of pesticide contamination is a unique environmental problem in that pesticides are deliberately introduced into the environment for beneficial purposes and/or monetary gains. They are not waste products as is characteristic of the large majority of environmental contaminants. Consequently, both the opponents and advocates of pesticide usage are numerous and steadfast in their beliefs. In the past, this has raised the argument to an emotional pitch, and, at present, continues to complicate the issue.

The effects of pesticide contamination are both short and long term. The short term effects often involve kills of non-target organisms due to ingestion of toxic levels of the pesticide. The long-term effects can be classified as carcinogenic, teratogenic (birth defects), mutagenic (genetic alteration), etc. Pesticides that accumulate in fat tissues can be spread throughout the organism when the energy in the fat tissues is required by the organism in times of hunger or stress. Thus, the time lag between the exposure and the onset of symptoms can be quite variable. The loss or reduction in certain species can have a considerable impact on the ecosystem. Ecologists generally agree that the presence of highly diversified species within an ecosystem increases its stability. Thus, the loss of individual species upsets predator-prey relationships causing imbalance and instability in the ecosystem. In sum, the effects of pesticide contamination are varied and complex, and are a major topic of research at the present time.

To equitably present the problem of pesticide contamination, one cannot ignore the benefits obtained from and the need for pesticides for weed and insect control. Although it is unlikely that a ban on pesticide usage would lead to starvation in the U. S., such an action would have severe economic implications. Production would decrease and prices of agricultural products would increase as the food supply diminished. It has been suggested that more agricultural land be brought into production to offset production losses from a ban on pesticide usage [7]. There is no guarantee that unchecked pests would quickly spread to the new land in production. On the contrary, this is highly likely. In many undeveloped countries, the situation is entirely different. Starvation and disease are still major problems even with all available agricultural land in production. Pesticides are invaluable in many such countries. It would be sheer folly to try to convince the underdeveloped countries that pesticide usage is harmful and that restrictions should receive consideration. With regard to other problems facing these countries, pesticide contamination has very low priority. In other words, concern for environmental pollution is strictly a luxury of the affluent countries.

The inescapable conclusion is that chemical pesticides will remain a permanent tool of the agriculturist and the public health scientist for some time to come. The programs of Integrated Pest Management of the U. S. Department of Agriculture emphasize the need to use a variety of control methods. This would include chemical pesticides, although on a much lower level than at present. Thus, it is clear that pesticide regulations must be designed to balance the detrimental and beneficial effects of pesticide usage. The recent shift in pesticide usage away from the chlorinated hydrocarbons to the less persistent pesticides is an encouraging trend. However, the less persistent carbonates and organophosphates which are gaining in popularity, are also more toxic. Consequently, it is important to understand the routes of pesticide loss from the field and the transport processes to the aquatic environment. Such an understanding, along with a knowledge of the effects of pesticides on non-target species, can provide an equitable basis for regulating the amount of pesticide to be released to the environment.

## PESTICIDE REGULATION

Prior to October , 1972, federal authority on the regulation of pesticides was derived from the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 requiring registration of all pesticides shipped in interstate commerce. Registration applications were filed with the Environmental Protection Agency (EPA) and renewed at 5 year intervals. EPA retained the authority to suspend or cancel registrations if use of the pesticide [1] presented an 'imminent hazard', of [2] resulted in injury to man or animals, when applied in accordance with label directions. This authority has been exercised a number of times. In 1971 registration cancellation proceedings were initiated against companies producing DDT, Mirix, 2,4,5-T, aldrin, and dieldrin. The subsequent ban on nearly all uses of DDT demonstrated the extent of authority of the EPA administrator under FIFRA in cases of extreme risk to man and the environment. The establishment of statutory limits on pesticide residues in foods remains an additional EPA regulatory tool.

In October, 1972, the Federal Environmental Pesticide Control Act (FEPCA) was written into law (PL92-516). FEPCA substantially increases federal authority over pesticide regulation from that provided under FIFRA. FEPCA allows the EPA Administrator to classify registered pesticides according to general or restricted use, or both. Moreover, FEPCA requires that all pesticides be registered; thus, requiring that state registration laws conform to present Federal law. Stop sale and seizure orders for pesticides in violation of the new legislation are also authorized. In sum, the level of pesticide regulation has advanced considerably with the new law.

With the passage of FEPCA, individual state pesticide regulatory agencies must revamp their existing regulations to assure conformance. At present, state pesticide laws vary in both severity and scope of regulation. With the increase in concern for environmental contamination, recent years have witnessed a proliferation of state pesticide laws. Generally these regulations involve one or more of the following:

1. Pesticide registration.
2. Permits for sale and/or use of pesticides.
3. Licensing of pesticide applicators.
4. Prohibition of certain hazardous pesticides, or, compilation of acceptable ones.
5. Regulations for handling and transport of pesticides, and disposal of pesticide containers.

Due to its inherent nature, the enforcement of pesticide regulations is performed most easily at the state or local levels. However, the non-uniformity of state regulations has led to jurisdictional disputes and enforcement problems.

Obvious by their absence are regulations stipulating the amount of pesticides which can be applied without detrimental external effects. The reasons for this are largely technological. Research is presently being conducted on the physical, chemical, and biological effects of various pesticide concentrations on plant and animal species. The complex interactions of pesticides when released to the environment have hindered the quantitative definition of the mechanisms involved in pesticide transport and attenuation. Laboratory research, aided by field experimentation, is progressing on these topics.

The present research effort is a study of the loss of pesticides from agricultural lands and an attempt to model the mechanisms by which pesticides reach a nearby watercourse. Available evidence points to surface runoff and sediment loss as the primary modes by which pesticidal contamination inflicts waterbodies. The reliable modeling of these mechanisms along with the pesticide interactions on soil and water can result in estimates of the fraction of applied pesticide reaching the stream channel. Such information, accompanied with estimates of allowable pesticide concentrations in the environment, can provide a basis for establishing allowable pesticide application rates. These rates could be determined for each of the various edaphic and climatic regions of the country. Such a methodology would allow regulation of pesticide use so as to minimize the detrimental environmental effects and still achieve the purposes of pesticide application.

A reliable pesticide transport model could provide the basis for formulation and evaluation of various management systems to restrict and control pesticide movement to receiving waters. Adjustment of model parameter values would represent the effects of proposed systems and techniques while analysis of model output (e.g., pesticide loss) would provide the basis for system evaluation. In this way, the relative efficiacy of terracing, coutour farming, pesticide regulations, and combinations of these and other management systems could be analyzed and evaluated. The end result would be a greater understanding of the proposed management system.

# SECTION IV

# MECHANISMS OF PESTICIDE LOSS AND TRANSPORT IN THE ENVIRONMENT

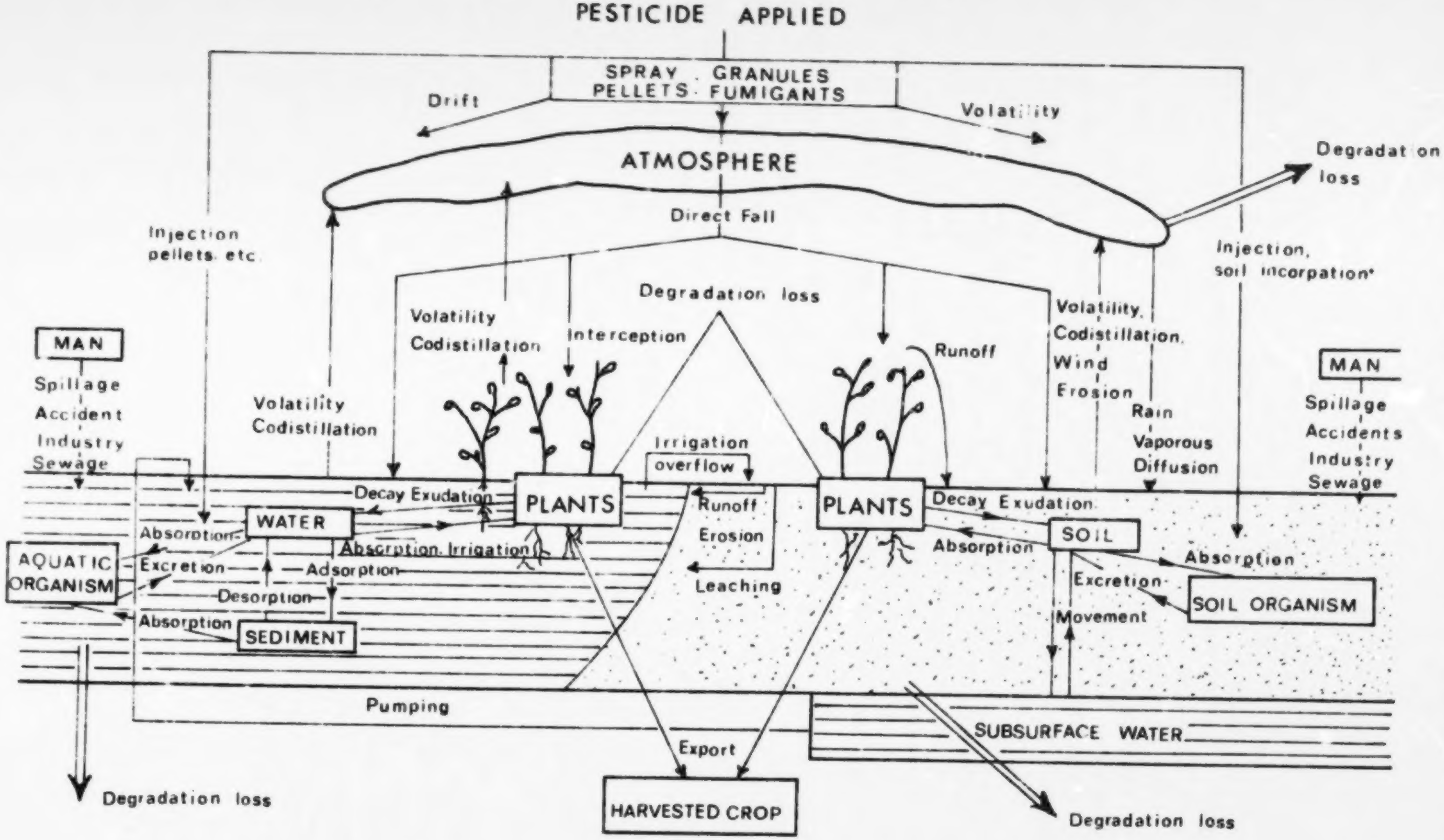
## PESTICIDE CYCLING IN THE ENVIRONMENT

Upon release to the environment, pesticides move by a myriad of transport mechanisms. Figure 1 attempts to portray the various pathways by which pesticides cycle through the environment. The term 'cycle' is quite appropriate here. Initially applied by Man, pesticide residues return to the human body through the ingestion of meat and harvested crops. The complexity of the maze of pathways shown in Figure 1 emphasizes the need to approach the problem at its origin -- the initial pesticide application. The President's Council on Environmental Quality has recognized that multi-media pollution problems, such as pesticides which involve air, land and water, are best analyzed by a materials balance approach [8]. A full accounting of the movement and loss of pesticides, subsequent to application, is necessary. Knowing the quantities of pesticide transported and retained by the various media, one could then attack the major mechanisms responsible for the detrimental effects of pesticide use. Figure 1 demonstrates that performing a materials balance on pesticides is not a simple matter. The mechanisms of transport and loss from the various media must be quantitatively understood, so that amounts of pesticide in transport can be predicted. Climatic, hydrologic, and edaphic conditions of the region plus the chemical properties of the pesticide will have an effect on the various mechanisms. Although many of these mechanisms are not completely understood at the present time, research is underway to explain the transport behavior of pesticides upon release to the environment.

## MECHANISMS OF LOSS FROM AGRICULTURAL LANDS

Pesticides are introduced into the environment by a variety of sources. Agricultural applications are obviously the major source. Spillage and accidents, industrial effluent, and municipal sewage are other instruments of pesticide pollution. These are either non-deliberate releases or point sources of pesticides, both of which must be handled in a different manner than applications to agricultural lands. A number of states have passed legislation

Figure 1. Pesticide cycling in the environment[10]


PESTICIDE APPLIED
SPRAY . GRANULES
PELLETS . FUMIGANTS
Drift
Volatility
ATMOSPHERE
Degradation loss
Direct Fall
Injection pellets. etc.
Injection, soil incorporation
Degradation loss
Volatility Codistillation
Interception
Runoff
Volatility, Codistillation, Wind Erosion
Rain Vaporous Diffusion
Volatility Codistillation
MAN
Spillage
Accident
Industry
Sewage
MAN
Spillage
Accidents
Industry
Sewage
Irrigation overflow
PLANTS
PLANTS
Decay Exudation
Decay Exudation
WATER
SOIL
Absorption
Absorption
Absorption
AQUATIC ORGANISM
Excretion
Absorption. Irrigation
Adsorption
Desorption
Absorption
SEDIMENT
Runoff
Erosion
Leaching
Excretion
Movement
SOIL ORGANISM
Pumping
SUBSURFACE WATER
Export
HARVESTED CROP
Degradation loss
Degradation loss

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

regulating the intrastate transport of pesticides, and the disposal of pesticide containers [9, 10] These two areas have proven to be a substantial source of spillage and accidential releases of pesticidal chemicals. Enforcement and regulation of these components is easier because of their point-source nature.

Because agricultural applications of pesticides constitutes the major release of pesticides to the environment, this area has received the greatest attention in the curbing of pesticide pollution. Following application, pesticide loss from agricultural lands occurs through surface runoff, sediment loss, volatilization, organisms (plant and animal) uptake, and degradation (microbial, photochemical, chemical). The relative significance of the various mechanisms is highly dependent on environmental conditions and pesticide properties. Movement of pesticides to a water course is of primary environmental concern because of possible effects on the aquatic ecology. Other than direct application, surface runoff and sediment transport have been recognized as the major routes to the aquatic environment[11,12]

Fortunately, a very small portion of the amount of applied pesticide will reach a watercourse. In general, the large majority of the application amount will volatilize or degrade by chemical, photochemical, and microbial agents. In some cases, pesticides will degrade into other chemicals more toxic and/or detrimental to the ecology of the area. Volatilization during and after application accounts for the escape of pesticides to the atmosphere. Upon entering the atmosphere, the areal extent of pesticide contamination is essentially unlimited. Atmospheric transport has been recognized as a major mechanism of widespread DDT contamination [13]

In summary, the movement of pesticides from agricultural lands is the major component of pesticidal contamination of the fresh water aquatic environment. Performing a materials balance on pesticides applied to agricultural lands would help to understand, qualitatively and quantitatively, the mechanisms involved in the loss of the applied pesticides. This report is part of a research effort designed to evaluate and model these mechanisms. The general goal is to estimate the amount of pesticide lost from agricultural levels that will reach and contaminate a watercourse. The remainder of the report describes the accompanying modeling program and preliminary results of that research effort.

# SECTION V

# PESTICIDE TRANSPORT AND RUNOFF MODEL COMPONENTS

Figure 2 illustrates the movement of applied pesticides as visualized by the Pesticide Transport and Runoff (PTR) Model. Four pesticide storage zones within the soil profile are assumed. Figure 3 presents the assumed depths of the various pesticide storage zones - surface zone, upper zone, lower zone, and groundwater zone. The assumed zone depths are necessary to specify the mass of soil involved in the pesticide-soil interactions.

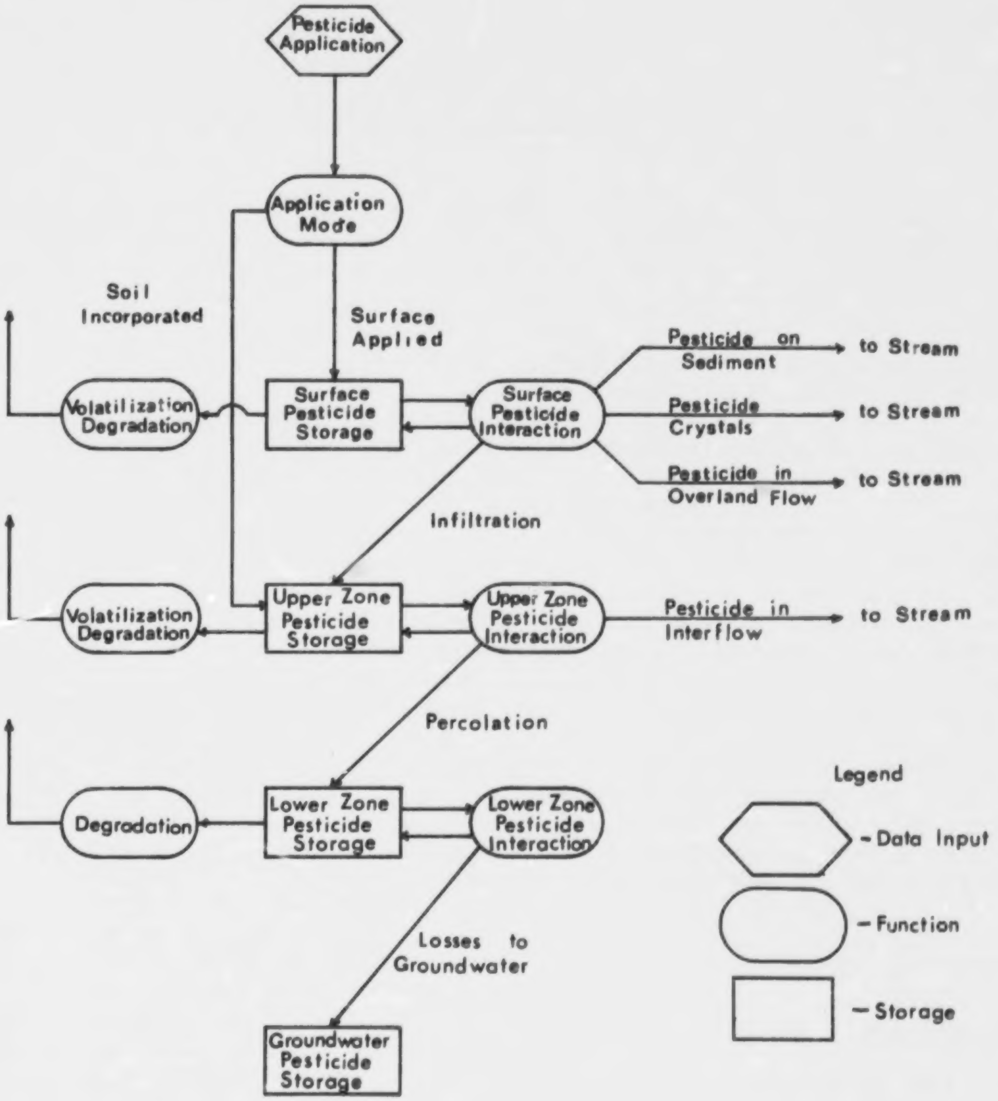
The PTR Model estimates the loss of pesticides from the land surface by simulating the mechanisms of surface runoff, sediment loss, pesticide adsorption-desorption, and pesticide volatilization and degradation. This chapter describes the various loss mechanisms and submodels included within the PTR Model. Initially the hydrologic model responsible for the determination of surface runoff and soil moisture storage is discussed. The sediment loss model estimates sediment production from the land surface based on input rainfall and surface runoff provided by the hydrologic model. The division of applied pesticide among the various phases (adsorbed, dissolved, and crystalline) is determinated by the pesticide adsorption-desorption model. This model, in conjunction with the hydrologic and sediment loss models, determines the amount of pesticide removed from the land surface by surface runoff and sediment loss. This section concludes with a discussion on the modeling of the loss of pesticides by volatilization and degradation. The actual structure and operation of the PTR Model is presented in Section VI.

## HYDROLOGIC MODEL

### The Hydrologic Cycle

The hydrologic cycle can be defined as follows: "The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration. Also called water cycle"[13]. Figure 4

Figure 2. Flowchart of pesticide movement in PTR Model


Pesticide Application
Application Mode
Soil Incorporated
Surface Applied
Volatilization Degradation
Surface Pesticide Storage
Surface Pesticide Interaction
Pesticide on Sediment
to Stream
Pesticide Crystals
to Stream
Pesticide in Overland Flow
to Stream
Infiltration
Volatilization Degradation
Upper Zone Pesticide Storage
Upper Zone Pesticide Interaction
Pesticide in Interflow
to Stream
Percolation
Legend
Degradation
Lower Zone Pesticide Storage
Lower Zone Pesticide Interaction
- Data Input
- Function
Losses to Groundwater
- Storage
Groundwater Pesticide Storage

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

Figure 3. Assumed soil depths for pesticide storage

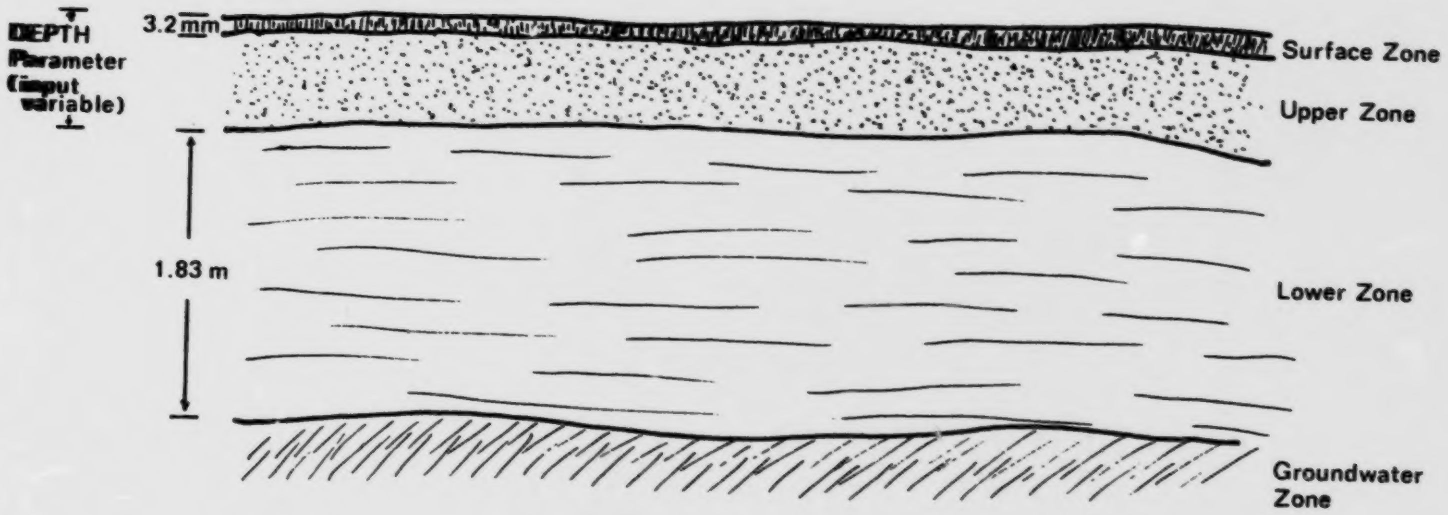
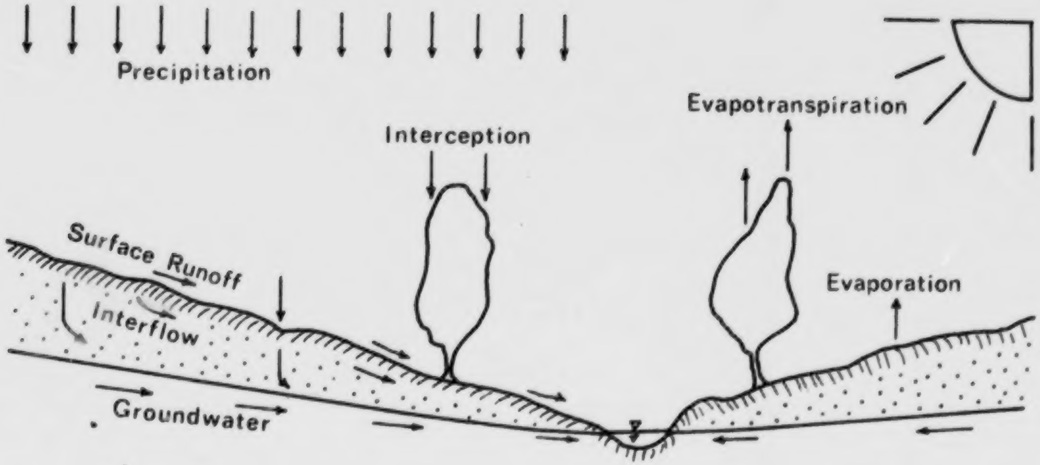

DEPTH
Parameter
(input
variable)
3.2 mm
1.83 m
Surface Zone
Upper Zone
Lower Zone
Groundwater
Zone

Figure 4. The hydrologic cycle


Precipitation
Interception
Evapotranspiration
Surface Runoff
Interflow
Evaporation
Groundwater

schematically shows the interactions and mechanisms that comprise the hydrologic cycle. The hydrograph of streamflow from a watershed is the end product of variable time and areal distributions of precipitation, evapotranspiration, soil moisture conditions, and physical watershed characteristics. Streamflow eventually reaches large water bodies, such as rivers, lakes, and oceans, evaporation from which is the major source of atmospheric moisture. The cycle is completed when atmospheric moisture condenses and returns to the land surface in the form of precipitation.

Since the movement of water is cyclical, without permanent sources or sinks, a pollutant entering any phase of the cycle can be transported by the water; hence, other phases of the cycle can be contaminated. Thus, an understanding and an ability to simulate the hydrologic cycle is instrumental in the study of the cycling of pollutants in the environment. Since pesticide movement from the land surface is the major mechanism of aquatic contamination, the present study is concerned largely with the land surface components of the hydrologic cycle.

## The LANDS Subprogram

Within the PTR Model, the LANDS subprogram simulates the hydrologic response of the watershed to inputs of precipitation and evaporation. LANDS simulates runoff continuously through a set of mathematical functions derived from theoretical and empirical evidence. It is basically a moisture accounting procedure on the land surface for water in each major component of the hydrologic cycle. Parameters within the mathematical functions are used to characterize the land surface and soil profile characteristics of the watershed. These parameters must be selected, tested and modified when LANDS is applied to a new watershed. Calibration is the process whereby the parameters are modified as a result of a comparison of simulated and recorded streamflow data for the watershed. Section VI on model structure and operation will describe the calibration process.

The mathematical foundation of the LANDS subprogram is derived from the Stanford Watershed Model (SWM) developed at Stanford University by Crawford and Linsley [14]. Subsequent improvements and refinements in the simulation algorithms of the SWM have been incorporated into the Hydrocomp Simulation Program (HSP). HSP is composed of three components whose functions involve data management and handling (named LIBRARY), hydrologic response of the land surface (also named LANDS), and kinematic channel routing of the land surface runoff (named CHANNELS). The LANDS subprogram of the PTR Model, with certain modifications is identical to the HSP LANDS module; moreover, the calibration parameters, listed in Table 1, are identical. For the sake of brevity, the basis and description of the mathematical functions of LANDS have been abstracted from the HSP Operations Manual and have been included in Appendix A. Figure 5 presents the flowchart of LANDS showing the interactions of the various land surface components that are described in Appendix A. Modifications to HSP LANDS which are incorporated into the PTR Model are explained subsequently.

Table 1. HYDROLOGIC MODEL (LANDS) PARAMETERS

A - A fraction representing the impervious area in a segment.

EPXM - The interception storage parameter, related to vegetal cover density.

UZSN - The nominal storage index for the upper soil zone.

LZSN - The nominal lower zone soil moisture storage parameter.

K3 - Index to actual evaporation (a function of vegetal cover).

K24L & K24EL - Parameters controlling the loss of water from groundwater storage. K24L is the fraction of groundwater recharge that percolates to deep groundwater tables. K24EL is the fraction of the segment area where shallow water tables put groundwater within reach of vegetation.

INFIL - This parameter is a function of soil characteristics defining the infiltration characteristics of the watershed.

INTER - This parameter defines the interflow characteristics of the watershed.

L - Length of overland flow plane.

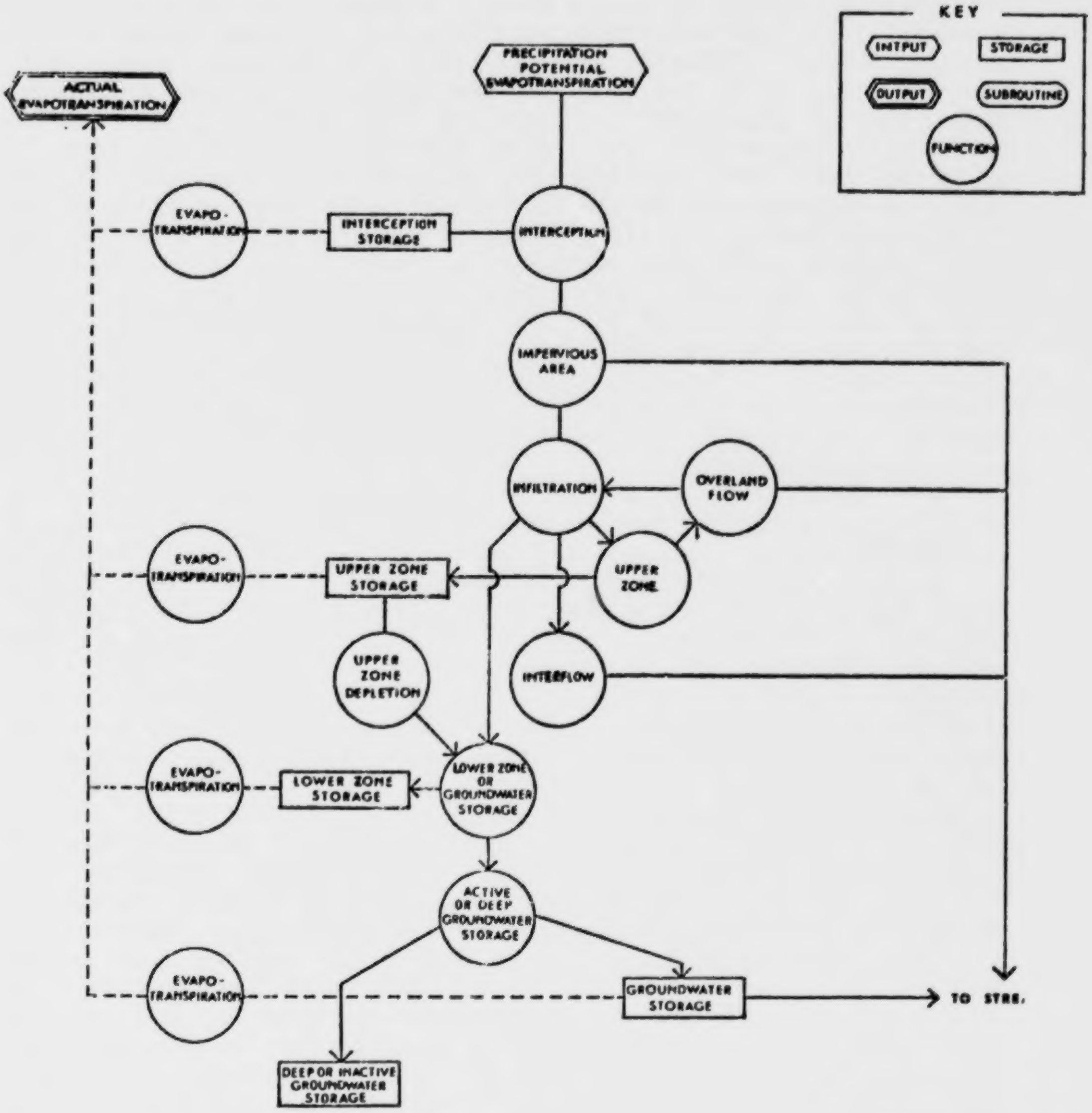
SS - Average overland flow slope.

NN - Manning's "n" for overland flow.

IRC & KK24 - The interflow and groundwater recession parameters.

KV - The parameter KV is used to allow a variable recession rate for groundwater discharge.

Figure 5. Lands flowchart


KEY
INTPUT
STORAGE
OUTPUT
SUBROUTINE
FUNCTION
ACTUAL EVAPOTRANSPIRATION
PRECIPITATION POTENTIAL EVAPOTRANSPIRATION
EVAPO-TRANSPIRATION
INTERCEPTION STORAGE
INTERCEPTION
IMPERVIOUS AREA
INFILTRATION
OVERLAND FLOW
EVAPO-TRANSPIRATION
UPPER ZONE STORAGE
UPPER ZONE
UPPER ZONE DEPLETION
INTERFLOW
EVAPO-TRANSPIRATION
LOWER ZONE STORAGE
LOWER ZONE OR GROUNDWATER STORAGE
ACTIVE OR DEEP GROUNDWATER STORAGE
EVAPO-TRANSPIRATION
GROUNDWATER STORAGE
TO STRE.
DEEPOR INACTIVE GROUNDWATER STORAGE

PESTICIDE RUNOFF | Hydrocomp

## Modification to HSP LANDS

The major concern in modifying the HSP LANDS module for pesticide transport was the desire to accommodate the expected areal variation in pesticide concentration over the land surface. It is generally accepted in hydrology that infiltration is time and area dependent; infiltration capacity will vary even within small watersheds with reasonably homogeneous soil characteristics. This areal variation in infiltration results in source areas, or zones, with low infiltration capacity within the watershed, contributing a large component of overland flow. Sediment loss will vary with the areal variation in overland flow. Since overland flow and sediment loss are the major mechanisms of pesticide transport to the water course, the low infiltration source areas will also experience a greater loss of pesticide than the remainder of the watershed. Consequently, the pesticide concentration on the land surface will vary, in spite of an initially uniform application. The pesticide concentration within the soil profile will also vary as a function of the volume of infiltration. Obviously, the extent of pesticide areal variation depends upon the solubility and transport characteristics of the specific pesticide applied, and upon topography and watershed characteristics. Natural hydrologic conditions and watershed characteristics are sufficiently non-uniform to justify the above described mechanisms leading to areal variations in infiltration and pesticide concentrations.

HSP LANDS employs a cumulative frequency distribution on infiltration capacity to account for the areal variation. Figure 6 graphically presents the infiltration function of HSP LANDS described in Appendix A. A mean infiltration capacity, f, is calculated and a linear approximation to the actual cumulative distribution is assumed. Interflow is determined as a function of infiltration and lower zone moisture storage. It is evaluated in Figure 6 as a second linear cumulative distribution denoted by f (c-1) (see Appendix A for a full description). Since the X-axis is unity (i.e. 100% of watershed area), the area of each wedge in Figure 6 represents the portion of the moisture supply allocated to each component. During any time interval, the available moisture supply is distributed to surface detention, interflow detention and infiltration. Overland flow and interflow are determined as losses from surface detention and interflow detention respectively. Lower zone moisture storage and groundwater components are derived from the infiltration component.

The LANDS subprogram of the PTR Model employs the same infiltration function as HSP LANDS, with one modification. The watershed is divided into five zones, each representing 20% of the total area. The zonal division is based on infiltration capacity. Schematically, Figure 7 shows that zone 1 will infiltrate much less water than zone 5; conversely, zone 5 will provide less overland flow than zone 1. Thus, the areal variation in infiltration capacity is approximated. Zones with lower infiltration capacity will serve as the major source areas for overland flow and sediment and pesticide

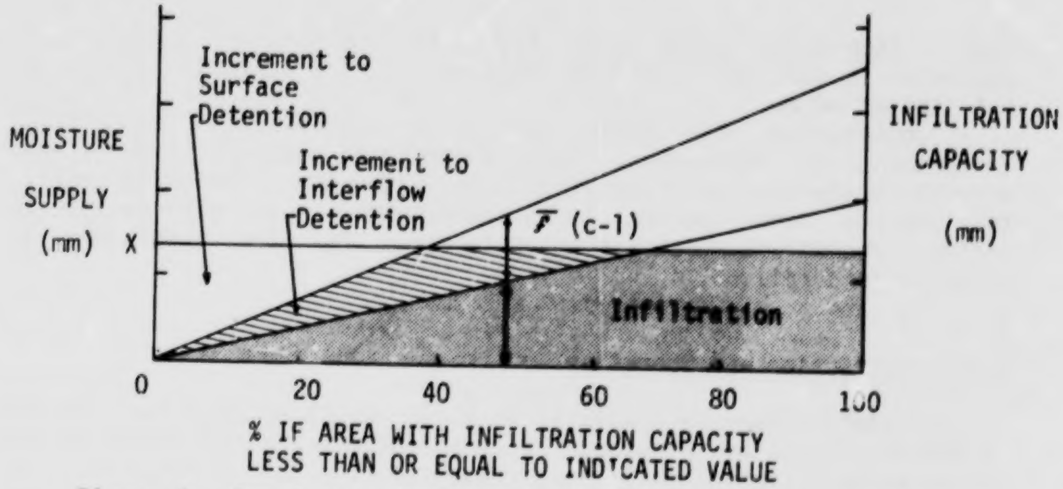

Increment to Surface Detention
Increment to Interflow Detention
MOISTURE SUPPLY (mm)
X
$\overline{F}$ (c-1)
INFILTRATION CAPACITY (mm)
Infiltration
0
20
40
60
80
100
% IF AREA WITH INFILTRATION CAPACITY LESS THAN OR EQUAL TO INDICATED VALUE

Figure 6. Cumulative frequency distribution of infiltration capacity showing infiltrated volumes, interflow and surface detention

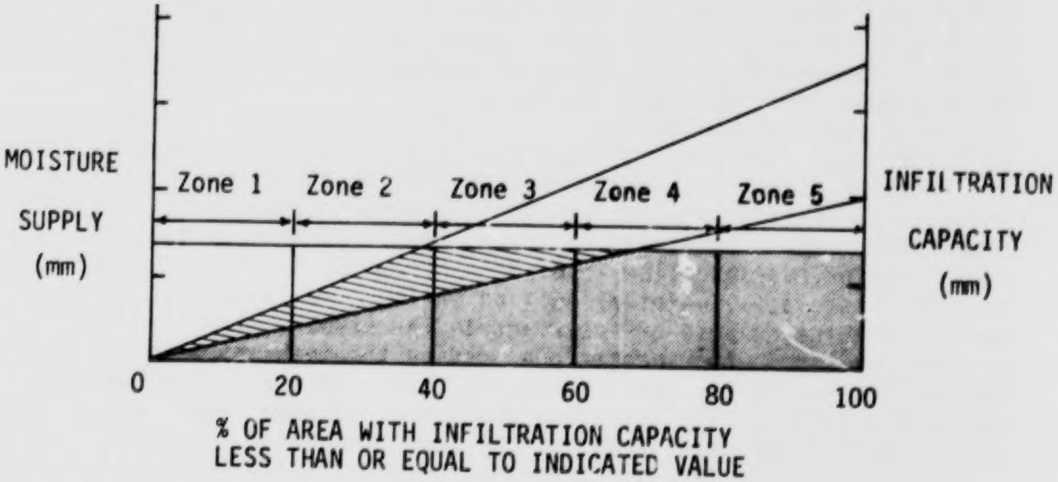

MOISTURE SUPPLY (mm)
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
INFILTRATION CAPACITY (mm)
0
20
40
60
80
100
% OF AREA WITH INFILTRATION CAPACITY LESS THAN OR EQUAL TO INDICATED VALUE

Figure 7. Source-zones superimposed on the infiltration capacity function

loss. Generally, zones with high infiltration will contain more pesticide in the soil profile because of the greater amount of infiltrated water.

Conceptually, the zones are not necessarily concentric, continuous, or contiguous. Each is connected directly to the stream channel by the overland flow plane. As with any simulation model, this source zone concept is an approximation. It is an attempt to portray mechanisms which are known to occur, but are impossible to simulate in detail.

## Model Description and Operation

The LANDS subprogram operates on a 5 or 15 minute time interval at the discretion of the user. Daily potential evapotranspiration and time-interval precipitation are required inputs. During each time interval, precipitation, in inches, is input and first encounters the interception function, as shown in Figure 5. Interception is a storage function dependent on vegetation and crop canopy. For agricultural lands, this will vary over the growing season. The change in crop canopy is administered by the MAIN program of the PTR Model which oversees input-output operations, time accounting, and general management of the component submodels. The MAIN program will be described in a subsequent section.

Once interception storage is filled, any remaining precipitation is added to the moisture supply of the infiltration function. The infiltration function, performs the basic division of available moisture into the components of surface detention, interflow detention, and infiltration. Surface detention includes the components of overland flow and an increment to upper zone soil moisture storage. Interflow detention is a delay mechanism controlling the release of interflow to the stream. Infiltration and percolation from the upper zone provide the means by which moisture reaches lower zone storages. From lower zone storage, the available moisture proceeds to active groundwater storage from which the groundwater component of streamflow is derived. Other than evapotranspiration, inactive groundwater (groundwater recharge) is the only other means of release of water from active groundwater storage. The mathematical functions describing the divisions involved in the LANDS subprogram are fully explained in Appendix A. The necessary input parameters are also defined.

Other than streamflow and losses to inactive groundwater, evapotranspiration is the only remaining loss component in the moisture balance performed in LANDS. Evapotranspiration occurs at different rates from each of the various moisture storages shown in Figure 5. Daily potential evapotranspiration values are input and transformed to hourly values by an empirical diurnal variation. Actual evapotranspiration is calculated on an hourly basis from interception, upper zone, and lower zone storages, and on an average daily basis from groundwater storage. From interception storage, evapotranspiration occurs at the potential rate. Any remaining potential is satisfied initially from the upper zone and then from the lower zone, depending on existing moisture conditions. Evapotranspiration from groundwater storage is controlled through an input parameter, K24EL, delineating the percent of watershed area where the groundwater table is close enough to the surface to allow evapotranspiration to occur (e. g. marshes, swamps, deep-rooted vegetation). Appendix A also describes in detail the functions simulating evapotranspiration from the various moisture storages.

The basic algorithms of the LANDS subprogram, as part of the Stanford Watershed Model, and the HSP, have been tested on over 200 watersheds in various regions of the country. However, its use on watersheds in the range of 4 - 20 hectares has been limited. Also, the modifications, described above, and its use in simulating pesticide transport are new endeavors. Problems arising from these new applications, and results of model testing are discussed in Section VIII - Model Results and Discussions.

## SEDIMENT LOSS SUBPROGRAM

### The Erosion Process

The process of erosion has been in operation throughout the history of the earth. The monuments of its glory surround the globe and shape its surface. Man marvels at the dichotomy of the minuteness of the Colorado River within the majestic environment it has shaped. Yet, despite the millions of acres and centuries of geologic evidence, the mechanism of erosion has not been mastered to the point where soil loss can be reliably predicted. Perhaps this will remain another of Mother Nature's secrets to which man's ingenuity can only achieve an approximation. However, attempts to understand and simulate the process continue in order to attain the best approximation possible.

Erosion is generally thought to consist of the detachment of soil particles, and movement of the particles to a channel in which they are transported to their ultimate destination. Our present understanding of the process involves its breakdown into the three mechanisms of sheet erosion, gully erosion, and channel erosion. Sheet erosion refers to the relatively uniform loss of topsoil across the soil surface. The impact of falling raindrops is an important process in this mechanism, detaching soil particles, or fines, from the soil aggregates. The fines are then available to be picked up and transported by overland flow.

Initially occurring as sheet flow, the overland flow will soon begin to concentrate into small rivulets due to the topography of the surface. Gully erosion becomes operative when the flow turbulence creates local forces sufficient to dislodge particles from the sides and head of the gully. As the gully grows deeper and wider, the momentum and inertia of the flow become significant factors in shaping the streambed and stream course. Here, channel erosion begins to influence the direction of the stream resulting in changes in the stream cross-section and meandering of the streambed.

In reality, the erosion process is gradual and continuous from the raindrop impact and overland flow pickup to the transport of sediment in the stream. There is no definitive dividing line between the mechanisms of sheet, gully and channel erosion. This conceptual model of the erosion process helps our overall understanding.

## Sheet Erosion

With regard to pesticide loss from agricultural lands, our interest in the erosion process is directed to the mechanism of sheet erosion. Included in this mechanism is the formation of small rills or rivulets which signify the primitive stages of gully erosion. Although gully erosion is significant in total sediment loss, the occurrence of gullies will not have a significant effect on pesticide loss because pesticide application is generally restricted to the surface or top few inches of soil. In this region, sheet erosion, including small rills, is the critical mechanism.

The hydrologic factors governing sheet erosion include the impact of raindrops and the occurrence of overland flow. As raindrops strike the land surface, soil aggregates are broken down and detached soil particles are dispersed in all directions. On a sloping surface, the raindrop splash will tend to move particles downhill. The angle of incidence of the raindrops will also be a function of wind velocity and direction. In any case, the soil movement by raindrop splash is quite small. Its main effect is the production of soil fines which are transported downslope by overland flow. The soil fines are either picked up from the surface by the overland flow or are added to the flow by the soil splash. In this way, the soil fines are transported downslope until a reduction in velocity allows the particles to settle. Subsequent overland flow will pick up the deposited particles and transport them another distance downslope. This process occurs repeatedly until the soil particles reach a major gully or stream channel where they become part of the sediment load of the stream.

The quantitative evaluation of the above processes is far from obvious. Theoretically, one would expect the soil detachment due to raindrop splash to be dependent on soil properties and on the kinetic energy of the raindrop in its collision with the soil surface. The kinetic energy, in turn, is a function of the mass and terminal velocity of the raindrop. Since the mass is the accumulated depth of rainfall, one could determine the theoretical kinetic energy if terminal velocities were known. Wischmeier and Smith [16] have shown that raindrop terminal velocities will vary with drop diameter and rainfall intensity. Natural rain storms will generally include a range of drop sizes and rainfall intensities. Moreover, wind velocity and crop canopy will have a significant effect on these factors.

Consequently, a strict theoretical approach would be impractical for field conditions.

Up to the present time, gross soil loss estimates have been based on either the Musgrave equation [17] or the Universal Soil Loss (USL) equation, developed by the Agricultural Research Service of the U. S. Department of Agriculture. These equations are similar in form, and both contain empirical components relating to soil erodibility, crop cover and management, overland slope and length and rainfall. The USL equation [18] is presented as follows:

$$A = B \times F \times G \times SL \times P \qquad (1)$$

where: A = average annual soil loss, tons per acre

B = relative soil erodibility factor

F = relative farming practice factor

G = relative cropping-management factor

SL = relative slope-length factor

P = rainfall erosion factor

The above equation yields the average annual soil loss per acre for the watershed. The factor which attempts to account for hydrologic conditions is P, the rainfall erosion factor, which is determined by:

$$P = (E\ I_{30})/100 \qquad (2)$$

where: E = Total storm kinetic energy, in foot-tons/acre-inch.
$I_{30}$ = Maximum 30-minute intensity during the storm, in/hour.

Wischmeier and Smith [16] have evaluated E as a function of rainfall intensity, and have further determined that the factor $E\ I_{30}$ demonstrated the best correlation for soil loss per storm among the factors tested. For this reason, the EI30 factor has been employed to evaluate P, the rainfall erosion factor in the USL equation. Negev [19] has noted that neither the Musgrave equation nor the USL equation contains a factor specifically accounting for the effects of runoff on soil loss. Since the sheet erosion mechanism depends on the occurrence of overland flow, applying these equations to a specific short time interval can lead to gross errors. Attempts to simulate the sheet erosion process on small watersheds must employ a short time interval. For this reason, neither the Musgrave nor the USL equations are applicable to continuous simulation of sediment loss from small watersheds.

## Sediment Loss Simulation

The simulation of sheet erosion as performed by the sediment subprogram is based on a sediment model developed by Moshe Negev at Stanford University[19]. Negev simulated the entire spectrum of the erosion process including sheet, gully, and channel erosion. Simulation was performed on an hourly basis. The accumulated daily sediment loads from Negev's model compared well with recorded values on an 81 square mile watershed in California. The simulated suspended sediment loads also agreed reasonably well with the recorded values.

The sediment subprogram of the PTR model employs Negev's functions to simulate the mechanism of raindrop impact and overland flow pick up and transport of soil particles. As opposed to Negev's model, rill formation and erosion is assumed to be included within sheet erosion process. On the small test watersheds, gully erosion did not appear to be significant, and consequently was not included within the model.

The production of soil fines from raindrop splash is modeled per unit area for each time interval as follows:

$$RER(t) = (1-COVER(T)) \times KRER \times PR(t)^{JRER} \qquad (3)$$

where: RER(t) = soil fines produced during time interval, T.

COVER(T) = percent vegetal cover as a function of the relative time within the growing season.

KRER = coefficient of soil properties.

PR(t) = precipitation during time interval, t.

JRER = exponent.

The term 'soil fines' is not defined according to particle size within the Model. Negev assumed that the 'wash load' portion of total sediment loss included particles less than 0.062 mm in diameter[19]. The 'soil fines' would include the finer particles of the wash load, i.e., approximately the silt and clay fraction. Implicitly, the soil fines can be defined as those particles disrupted and detached by the force of raindrop impact.

The soil fines produced by the raindrop impact are immediately available for transport by overland flow if overland flow is occurring within the time interval. If overland flow is not occurring, such as during the initial or final stages of the storm period, the soil fines accummulate on the soil surface. Thus, a reservoir of fines is deposited on the surface available for pick up and transport by subsequent overland flow. The pick up of deposited soil fines is a function of the overland flow occurring during the time interval and the total amount of deposited fines on the surface. This mechanism is modeled per unit area for each time interval by the relationship:

$$SER(t) = KSER \times SRER(t-1) \times ROSB(t)^{JSER} \quad (4)$$

where: $SER(t)$ = fine pick up during time interval, t.

$KSER$ = coefficient of pick up.

$SRER(t-1)$ = reservoir of deposited fines existing at the beginning of time interval, t.

$ROSB(t)$ = overland flow occurring during time interval, t.

$JSER$ = exponent.

Thus, the total contribution to sediment loss during any time interval is the sum of the soil fines production from raindrop impact plus the fines pickup by overland flow. The subprogram also includes soil washoff component from impervious areas, although this is not significant for agricultural lands.

The source-zone concept described in Section V allows the calculation of the overland flow component from each zone within the watershed. The zones with lower infiltration will experience greater overland flow and, thus, greater sediment loss. The overland flow component from each zone is used to calculate the soil fines pickup for that zone. Consequently, during each time interval, the sediment production from each zone is determined from the above equations. The sum of the zonal contributions is the total sediment load to the stream. This zonal concept attempts to simulate the areal variation in sediment loss due to the overland flow variation.

## PESTICIDE ADSORPTION - DESORPTION MODEL

### Mechanism of Pesticide Adsorption-Desorption

The interactions between pesticides and the soil to which they are applied are undoubtedly the most critical mechanisms in the determination of pesticide loss from agricultural lands. Bailey and White[20] have concluded that pesticide adsorption-desorption, the attraction of pesticidal molecules to soil particles, directly or indirectly effects all factors known to influence the fate and behavior of pesticides in soil systems. Pesticide adsorption provides the route of transport to stream channels for many pesticides. Moreover, the strength of this adsorption will affect the importance of surface runoff as a mechanism of transport for soluble pesticides. The mechanisms of volatilization, degradation, organism uptake, and movement of pesticides are all affected by the adsorption-desorption interactions which occur. Consequently, in order to attempt to simulate the loss of pesticides from the soil, one must adequately understand this complex phenomenon.

A number of factors determine the extent of pesticide adsorption-desorption in a soil-water system. King and McCarty[21] have classified these factors into three groups relating to (1) the nature of the soil, (2) the nature of the pesticide, and (3) the influence of environmental factors. Soil characteristics of major importance include clay content, major clay mineral type, organic matter content, and cation exchange capacity. Surface charge density and surface area will also have an effect on pesticide adsorption. The significant pesticidal properties include molecular weight, chemical structure, water solubility, acidity or basicity, and polarity. In general, the extent of pesticide adsorption will depend upon the specific combination of soil and pesticide properties in any given situation. Also, since many of the determining factors are interrelated, the individual effect of separate soil and pesticide characteristics is extremely difficult to investigate. An elaboration of the possible effects of all these factors is beyond the scope of this report. A number of articles[20, 22, 23] have summarized the existing state of knowledge and research on the determinant factors of pesticide adsorption-desorption. The reader is referred to these references for additional information.

The influence of environmental factors is believed to be less significant than pesticide and soil properties in the adsorption-desorption reaction. Soil temperature, soil moisture content, and climatic conditions are usually considered to be the major environmental factors. Although rainfall, runoff, and other climatic conditions are critical determinants of pesticide loss from the soil, their importance is limited in the actual pesticide-soil interaction.

Because of the lack of quantitative relationships describing the effects of the above mentioned factors on pesticide adsorption, the model simulating this process is based on a number of assumptions. Testing the validity of these assumptions from the model output was a major portion of the present research effort. The model and accompanying assumptions are described subsequently.

## Model Description

The algorithm currently in use to model pesticide adsorption and desorption on soil is as follows:

$$X/M = K\,C^{(1/N)} + F/M \qquad (5)$$

where: X/M = Pesticide adsorbed per unit soil, mg/gm,

F/M = Pesticide adsorbed in permanent fixed state per unit soil, F/M is less than or equal to FP/M, where FP/M is the permanent fixed capacity of soil in mg/gm for pesticide. This can be approximated by the cation or anion exchange capacity for that particular soil type

C = Equilibrium pesticide concentration in solution, mg/ml;

N = Exponent;
K = Coefficient;

This model was derived from the work of Weber and Weed [24], [25], Faust and Zarins [26] and others. It combines the standard Freundlich model x/m = K C (1/N) with an empirical term. The empirical term describes pesticide which is adsorbed so strongly that the surrounding dissolved pesticide concentration is too small to be measured experimentally. Weber and Weed [24] have shown that this initially adsorbed pesticide will not desorb under repeated washing; hence, this initial adsorption is called the permanently fixed pesticide. Pesticide adsorbed into the permanent fixed state will be assumed unavailable for desorption. The permanent fixed state is assumed to have a maximum capacity, FP/M, which must be determined from experimental adsorption isotherms for the pesticide-soil combination under consideration. All available dissolved pesticide is assumed to be adsorbed into the permanent fixed state until FP/M is reached. The remaining dissolved pesticide is then subject to reversible equilibrium adsorption as governed by Freundlich equation. The model is presented graphically in Figure 8.

The basic assumptions underlying this model are as follows:

(1) Permanent fixed adsorption is irreversible.

(2) Single-valued reversible adsorption occurs above the FP/M concentration.

(3) Reaction is pH independent.

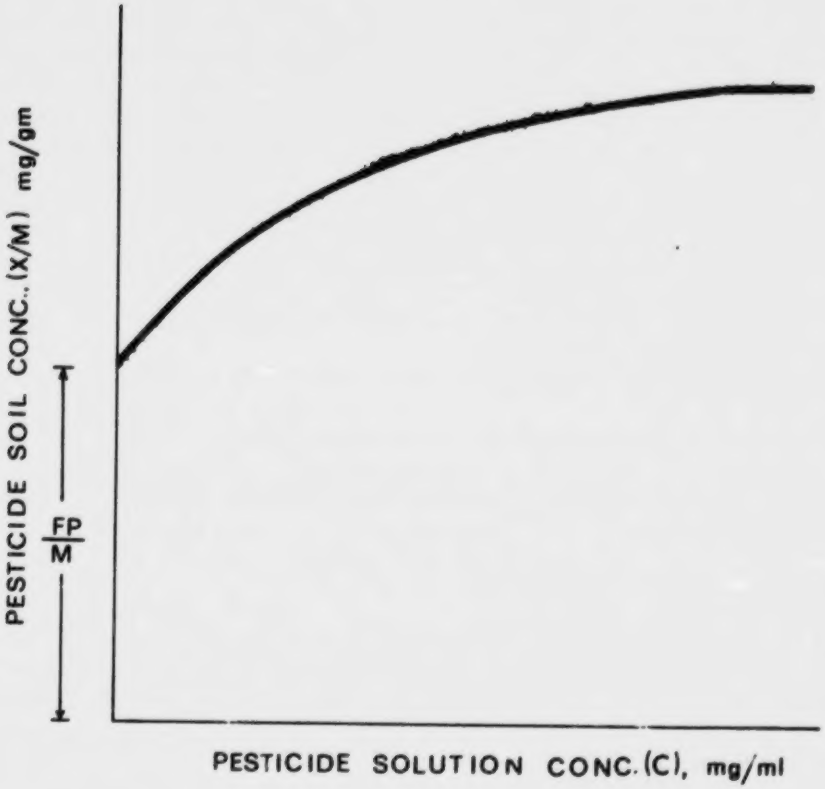
(4) No competing ion effect occurs.

(5) Adsorption is time independent, i.e. equilibrium is assumed.

Assumption 1 appears to be substantiated by the work of Weber and Weed [24]. For the majority of pesticides, the permanently fixed portion will be negligible. However, the existing model can accommodate those pesticides, such as paraquat, which are so strongly adsorbed to soil particles that their mode of transport from the land surface is exclusively by sediment loss.

Assumption 2 states that the division of the pesticide between the water and sediment phases will follow the same curve in both the adsorption and desorption cycles, i.e. a single-valued, reversible adsorption-desorption relationship is assumed. Davidson and McDougal Van Genuchten, Davidson, and Wierenga [28], and Davidson, Mansell, and Baker [29], have shown that the reaction is non-reversible for a number of pesticides. The end result of assumption 2 is that predicted pesticide concentration on sediment would be less than recorded values. The field data is inconclusive.

Figure 8. Pesticide adsorption–desorption model



However, the existing laboratory evidence suggests that the addition of a non-reversible adsorption-desorption model warrants further study and consideration (see Section IX - Recommendations for Future Research).

The third and fourth assumptions are more the result of necessity than of experimental evidence. On the contrary, both the pH and the availability of competing ions will affect the adsorption-desorption reaction. The lack of quantitative relationships describing these effects is the reason for the assumptions. However, the existing model clearly requires laboratory determination of the Freundlich adsorption constants for the specific pesticide and soil system. Consequently, the adsorption-desorption constants will inherently correct for the pH and competing ion conditions of the specific soil system. Variations in ph over the growing season are thought to be negligible. Also, adsorption sites are considered much more prevalent than available pesticide ions. Therefore, the third and fourth assumptions appear to be reasonable, and will likely introduce minimal error in the final results.

Assumption 5 states that the adsorption-desorption reaction is essentially instantaneous when the time required to reach equilibrium is compared with infiltration times through soils. Thus, in accordance with the Freundlich isotherm, equilibrium conditions are assumed to exist within any time interval. Time intervals employed in the model include five or fifteen minutes during storm events, and daily intervals otherwise. Hornsby and Davidson [30] have shown that under saturated conditions, adsorbed and solution phases of fluometuron are not in equilibrium at an average infiltration rate of 5.5 cm/hr. (2.165 in/hr.). whereas equilibrium does exist at 0.59 cm/hr ( 0.23 in/hr). Obviously, the range of infiltration values will depend on the pesticide and specific soil system. However, in natural soil systems, infiltration rates will generally fall near the lower and middle values of this range. Consequently, the existence of equilibrium conditions appears to be a reasonable assumption that may be violated infrequently during some storm events. Further study on the significance of these events is needed as more data becomes available.

In summary, a model is only an approximation to real-world conditions. The above assumptions have been adopted to provide a more manageable framework to the problem of pesticide adsorption in natural soil systems. These assumptions are based on mechanisms and factors which are known to be operative under laboratory conditions, but whose significance under field conditions is unknown. The vagaries of nature have yet to be reproduced in laboratory experiments. This is a familiar problem in the application of laboratory research to natural conditions. The results of continuing testing of the PTR Model should provide a basis for evaluating the validity of the above assumptions under natural field conditions. Those assumptions found to be invalid will provide the basis for further Model improvements.

## PESTICIDE VOLATILIZATION AND DEGRADATION MODEL

The loss of pesticides by volatilization and degradation is generally the major component in the establishment of a materials balance of the applied pesticide. A number of studies [31, 32, 33] have shown that these mechanisms are operative and generally account for the largest portion of pesticide loss subsequent to application. The relative significance of volatilization and degradation is highly dependent on the chemical properties of the pesticide. Although some selected pesticides are non-volatile and/or non-degradable, the majority of available pesticides are vulnerable in varying degrees to these mechanisms.

Volatilization is most significant during and immediately following application. Loss during application is highly variable depending on climatic conditions, pesticide formulation, and methods of application [31]. Immediately following application, volatilization losses remain at high levels for a number of days and then decrease rapidly to low but continuous levels. During this time, variations in volatilization rate are due to soil and pesticide characteristics, and environmental conditions [34, 35].

Degradation of pesticides is accomplished through chemical, photochemical, and microbial mechanisms. The relative significance of the various mechanisms is highly dependent on pesticide characteristics and environmental conditions. Although laboratory studies have been performed on the various degradation mechanisms, the extrapolation of the results to field conditions is highly questionable.

The volatilization and degradation models used in the PTR Model are derived from theoretical considerations and laboratory results. Consequently, the use of these models to predict volatilization and degradation losses from natural watersheds has not been substantiated or verified. Hopefully future work will provide data on which calibration of the models can be performed. Pesticide concentration on the land surface is partially a function of accumulated losses from volatilization and degradation. Also pesticide loss from surface runoff is dependent on surface pesticide concentrations. The present volatilization models have been included in order to be available if sufficient data for calibration is developed. The degradation model, a simple first-order decay, was included to reflect a decrease in surface concentration over the growing season in order to more realistically simulate the pesticide lost by surface runoff.

### Volatilization of Soil-Incorporated Pesticides

The sub-model for determining the volatilization of soil-incorporated pesticides is based on work performed by Mayer, Letey, and Farmer [36]. In that investigation, an analogy is drawn between heat flow and pesticide diffusion through the soil. Five submodels were presented for differing boundary conditions. All submodels consider volatilization a diffusion-based phenomenon and ignored transport via mass flow. Thus, diffusion is assumed to be the rate limiting mechanism for pesticide flux occurring from the land surface for soil-incorporated pesticides. The basis for our model is the following equation:

$$F = DCo/\sqrt{\pi Dt} \tag{6}$$

where: F = pesticide flux
D = diffusion coefficient
Co = initial pesticide concentration
t = time since application

Modification of the value of D, the diffusion coefficient, accounts for the effects of various environmental factors such as temperature, soil moisture, and physical soil properties. Ehlers et al [37] have investigated the effects of these environmental factors on lindane diffusion in soils. The results of that work have been used in our model to correct the value of D for environmental conditions. The actual equation used in the model is an approximation to equation (6) so that the mechanism can be described in a time-independent manner. This was necessary in order to avoid problems associated with a continuous bookkeeping of time since application, and pesticide concentrations due to reapplication.

Model Assumptions - The validity of equation (6) is dependent on two basic assumptions:

(1) Pesticide concentration above the soil surface remains at zero, and

(2) The initial pesticide concentration, Co, remains essentially constant at the lowest depth of soil incorporation.

In the heat flow analog, the first assumption would correspond to the case of determining the heat flux from an infinite (constant temperature) heat source, where the surface temperature is maintained at a constant lower temperature. Farmer et al [34] and Mayer, Letey, and Farmer [36] have shown that extremely small air flow rates are needed to maintain a negligible pesticide concentration above the surface. Thus, assumption (1) above appears reasonable except in those cases where vegetal cover and crop canopies stagnate the air and allow a buildup of pesticide concentration to occur at the soil surface. The importance of this situation will need to be considered and investigated when sufficient data is available for model testing.

Assumption (2) is obviously an approximation since the pesticide concentration at the lowest depth of incorporation will decrease from pesticide degradation and mobility. However, the approximation seems reasonable for an initial model upon which improvements and modifications can be made. Calculations for dieldrin by Mayer, Letey, and Farmer [36] using equation (6), have shown that 2,000 days would be required for Co to be reduced by 1% at the bottom of the soil column 11 cm deep (assuming a constant D = 2.3 mm 2 /wk). Thus in the initial weeks following pesticide application, the approximation would be valid. However, the long-term volatilization rates may be too high and thus require adjustment.

Environmental Factors - The major environmental conditions which will have an effect on volatilization of soil incorporated pesticides include surface temperature, soil moisture, and physical soil properties. The work of Ehlers et al [37] on lindane diffusion is used to adjust the diffusion coefficient for the existing environmental conditions.

Working with organochlorine insecticides, Farmer et al [34] reported that vapor pressure was the most significant factor in volatilization losses, and that pesticide concentration was the next most important. Igue et al [35] and Spencer, Claith, and Farmer [38] have shown that the vapor density (calculated from the ideal gas law, vapor density = P x M/RT) of dieldrin will increase with relative humidity and soil water content until the equivalent of one molecular layer of water molecules is held in the soil. With further increases in soil water content, the vapor density remains constant. The conclusion to be drawn is that vapor density, and therefore, pesticide volatilization, will remain constant with respect to soil water content once a minimum value of soil moisture is obtained. Ehlers et al [37] has reported a similar relationship between soil water content and the diffusion coefficient of lindane. For a soil water content greater than 4-5%, the diffusion coefficient of lindane remains essentially constant Consequently, the model assumes that the diffusion coefficient in equation (6) will be independent of soil moisture for our agricultural lands.

Farmer [39] has noted that this is a reasonable assumption except for the variation in soil moisture with depth. The problem here is that during dry periods, pesticide will diffuse to the dry soil surface and accumulate there because volatilization will be inhibited by the lack of soil moisture. Consequently, this accumulated pesticide will volatilize rapidly immediately following a storm period when moisture is available. The model neglects this mechanism since it is possible that the total amount lost will not be affected significantly.

Variation of the diffusion coefficient with temperature changes has been investigated by Ehlers et al [37] for the case of lindane in Gila salt loam. Ehlers divided the diffusion coefficient into components representing diffusion in the vapor and non-vapor phases of the pesticide. The relationship between the total diffusion coefficient (sum of vapor and non-vapor phases) and temperature was shown to be exponential, and of the following form:

$$D = Ae^{BT} \qquad (7)$$

where: $D$ = Total diffusion coefficient, in $mm^2$ /wk
$T$ = Temperature in degrees, C
$A$, $B$ = Constants

The values of A and B for lindane in Gila silt loam are 0.42 and 0.11, respectively. Equation (7) is employed in the soil-incorporated pesticide volatilization model. The values of A and B need to be determined for the specific pesticide and field conditions, or from experimental values.

At present, the influence of physical soil properties on the diffusion coefficient has not been quantified to a significant extent. Ehlers et al [37] has reported an almost linear relationship between bulk density and the diffusion coefficient for lindane in Gila silt loam. However, additional evidence has not been uncovered at this time. Consequently, the model requires a diffusion coefficient for the specific soil conditions. Future improvements in the model could be aimed at possible adjustments in the diffusion coefficient for the physical soil properties.

### Volatilization of Surface Applied Pesticides

Surface applied pesticides present a slightly different problem than soil incorporated pesticides. The main differences relate to the higher concentrations of the surface applied pesticide, and the greater direct exposure to environmental conditions, such as temperature and wind. The model is based on investigations by Farmer [40] and on conventional empirical relations for determining water evaporation. The resulting equation which is used is:

$$F = C \times U \times (EVC/M^{1/2}) \qquad (8)$$

where: $F$ = pesticide flux
$U$ = Wind velocity
$EVC$ = Equilibrium vapor concentration
$M$ = Molecular weight of the pesticide
$C$ = Constant

The equilibrium vapor concentration, EVC , is a function of pesticide concentration and surface soil temperatures. The value of C is determined through calibration for the specific watershed.

Model Assumptions - Farmer investigated pesticide flux from treated sand for four different pesticides at three different air flow rates across the surface of the sand. He obtained reasonable agreement between experimental values and those values calculated from:

$$F = K \times (SVC/M^{1/2}) \qquad (9)$$

where: F = Pesticide flux
SVC = Saturation vapor concentration (equivalent to EVC in equation 8)
M = Molecular weight
k = Constant

Values of k were determined experimentally for each pesticide for each flow rate. An average value of k for all four pesticides was used to determine the calculated flux at each flow rate. The main conclusion here is that pesticide flux can be adequately represented as the product of the pesticide vapor concentration and a constant, k, which is a function of the air flow rate. This relationship is similar to the following equation often used to determine water evaporation:

$$E = C \times U \times (e_w - e_a) \quad (10)$$

where: E = Evaporation
U = Wind velocity
$e_w$ = Vapor pressure of water
$e_a$ = Vapor pressure of water in air
C = Constant

Equation (8) which is used initially in the model was developed conceptually from equations (9) and (10). The value of k was replaced by wind velocity times a constant, C, which is evaluated through calibration and testing.

An obvious problem with the model is that volatilization will not occur if wind velocity is zero. This problem was also recognized in the case of water evaporation. The original Meyer equation for evaporation, from which equation (11) was derived, is as follows:

$$E = C_1 \ (1 + C_2U) \ (e_w - e_a) \quad (11)$$

$C_1$ and $C_2$ are constants. Thus, if wind velocity is zero, some evaporation will still occur through the mechanism of molecular diffusion. It was argued that this component was insignificant in water evaporation. The occurrence of zero wind movement in a 24 hour day is quite rare, e.g. in Denver only 2 days of zero wind movement occurred in 20 years of record. For pesticide volatilization, this adjustment for zero wind movement may be quite significant since volatilization will likely occur in the absence of wind. However, this adjustment is presently neglected until calibration and testing results necessitate its inclusion. The evaporation equation is based on a vapor pressure (or vapor concentration) difference between the water and air. Our model essentially assumes that wind velocity will be non-zero and large enough to disperse pesticide vapor at the soil surface. Thus, the vapor concentration of the air at the soil surface is assumed to be zero because of the wind component.

A major assumption in the model relates to the dependence of the equilibrium vapor concentration on pesticide soil concentration.

Spencer, Claith and Farmer [41] have shown that the vapor concentration (or density) of dieldrin increases with dieldrin soil concentration until a value of 25 ppm is reached in the soil. For pesticide soil concentrations greater than 25 ppm, the vapor concentration is essentially constant and equal to the vapor concentration of pure dieldrin. Thus, it appears that surface applications of pesticides will initially volatilize from the soil as quickly as from the pure pesticide. Farmer et al [42] reached a similar conclusion when comparing lindane and DDT to dieldrin, except that the long-term rates of volatilization would be smaller because the pesticide loss would reduce the pesticide soil concentration. However, the assumptions in our model will be that the equilibrium vapor concentration in equation (8) will be that of the pure substance. Long-term volatilization rates will have to be adjusted when data is available to prove that this assumption is no longer valid.

Environmental Factors - Temperature, wind, soil moisture, and physical soil properties all have an effect on volatilization of surface applied pesticides. Wind velocity is included directly in the model equation. Soil moisture and physical soil properties will affect volatilization largely by their influence on the competing mechanism of pesticide-soil adsorption. The greater the adsorption to soil particles, the less opportunity for volatilization. The model assumes that volatilization of surface applied pesticides will be similar to volatilization from the pure pesticide. Consequently, soil properties should not have a major effect. If calibration and testing prove this assumption to be invalid, then further adjustments and improvements will be required.

The major effect of surface temperature will be to change the pesticide vapor pressure which in turn affects the equilibrium vapor concentration. Spencer and Claith [43,44] have investigated the effects of temperature on the vapor pressures of dieldrin and lindane. The general form of the relationship is:

$$\mathrm{Log}_{10} P = A - B/T \qquad (12)$$

where: $P$ = Vapor pressure, mm of Hg.
$T$ = Temperature, in degrees, K
$A$, $B$ = Constants

The results of Spencer and Claith are used to adjust the vapor pressure of the pesticide for temperature changes. The resulting equilibrium vapor concentration is calculated from the ideal gas law as follows:

$$EVC = P \times M/RT \qquad (13)$$

This value of EVC is then used in Equation (8) to determine the pesticide flux for any time interval. The values of A and B in the temperature adjustment are determined either experimentally or from the literature.

## Pesticide Degradation

As mentioned previously, pesticide degradation occurs by a variety of mechanisms involving chemical, photochemical, and microbial agents. As with volatilization and adsorption, environmental factors have significant impact on the various degradation processes. The quantification of the various degradation mechanisms and the effect of environmental conditions is a current research topic of substantial importance. However, no definitive models of total pesticide degradation are currently available which would be amenable to inclusion in the PTR Model. The staff at SERL is presently studying various degradation mechanisms with the goal of developing such models.

A few studies have shown that total degradation for certain pesticides can be approximated by a first-order decay function[45,46] Fractional order or Michaelis-Menton kinetics have shown to be more accurate in other situations [47] Considering such inconclusive evidence, a first-order degradation function has been assumed for the PTR Model. This assumption is necessary so that the amount of pesticide available for transport by surface runoff and sediment will be gradually diminished over time. Thus, more realistic estimates of the concentration and volume of pesticide in surface runoff can be obtained. As research progresses in this area, the first-order decay can be replaced by a model which would be capable of adjusting degradation rates for the specific soil, pesticide, and environmental conditions.

In the PTR Model, the user supplies a daily degradation factor, which reduces the amount of pesticide in storage at the end of each day. The same factor is applied to each of the pesticide storage zones within the soil profile-surface, upper zone, and lower zone. Since the majority of pesticides never reach the groundwater storage zone, no pesticide degradation is considered to occur from that zone.

# SECTION VI

# PTR MODEL STRUCTURE AND OPERATION

## MODEL STRUCTURE

The PTR Model is structured about a main, or executive program, which controls the operation of six (6) accompanying subprograms. The MAIN program also controls input and output operations, manages the time-keeping operations, and performs the transfer of data between subprograms. The MAIN program and subprograms are listed in Table 2, along with the time intervals and functions which are performed. The six subprograms simulate pesticide volatilization and degradation, surface runoff, sediment loss, and pesticide interaction in the various soil storages. A complete listing of the PTR Model is included in Appendix C.

## MODEL OPERATION

The Model operates continuously on a number of different time intervals. The basic manner of operation is shown in Figure 9. The VOLDEG subprogram adjusts the pesticide storages on a daily basis for loss of active pesticide by volatilization and degradation. For days in which rain occurs, Model operation follows the solid line in Figure 9, operating on a five or fifteen minute interval for the subprograms LANDS, SEDT, ADSRB1, ADSRB2, and ADSRB3. The choice of a five or fifteen minute time interval depends on the time intervals of the input rainfall. For days in which rainfall does not occur, the model operation follows the dashed line in Figure 9: SEDT is bypassed; LANDS operates on five or fifteen minutes; and ADSRB1, ADSRB2, and ADSRB3 operate on a daily basis. The MAIN program monitors the passage of real time and keys the operation of the separate subprograms at the proper time intervals.

The PTR Model is written in the IBM FORTRAN IV language and was developed and run on the Stanford University IBM 360/67 computer. The Model operates most efficiently in a two-step procedure. The first step involves the compilation of the program and the storage of the compiled version on disk or magnetic tape. In step two, the compiled Model is provided the necessary input data and is executed. Thus, the

Model can operate a number of types of different input data with a single compilation. The format of the input and output is described below.

Table 2. PTR MODEL SUBPROGRAMS

| Name | Function | Operation Time Intervals |
|---|---|---|
| MAIN | Executive program | Not Applicable |
| LANDS | Hydrologic model | 5-min., 15-min. |
| SEDT | Sediment loss model | 5-min., 15-min. |
| ADSRB1 | Surface Pesticide Interaction | 5-min., 15-min.<br>Daily |
| ADSRB2 | Upper Zone Pesticide Interaction | 5-min., 15-min.<br>Daily |
| ADSRB3 | Lower Zone and Groundwater Pesticide Interaction | 5-min., 15-min.<br>Daily |
| VOLDEG | Pesticide Volatilization and Degradation | Daily |

## MODEL INPUT AND OUTPUT

### Model Input

Input data is accepted by the Model on a sequential basis in English or Metric units. Model parameters, daily potential evapotranspiration, average daily soil temperature, daily wind movement, and rainfall data are input in that order as shown in Table 3. To simplify input procedures and reduce computer storage requirements, the hydrometeorologic data is input on a calendar year cycle. Each block of data in Table 3 represents all daily values for the full year or for that portion of the calendar year which is to be simulated. Thus, if simulation begins on July 1, 1972 and ends on February 15, 1973, the hydrometeorologic data sequence (evapotranspiration, soil temperature, wind, rainfall) for July 1 through December 31, 1972 is followed by the hydrometeorologic data for January 1 through February 15, 1973.

Figure 9. PTR Model structure and operation

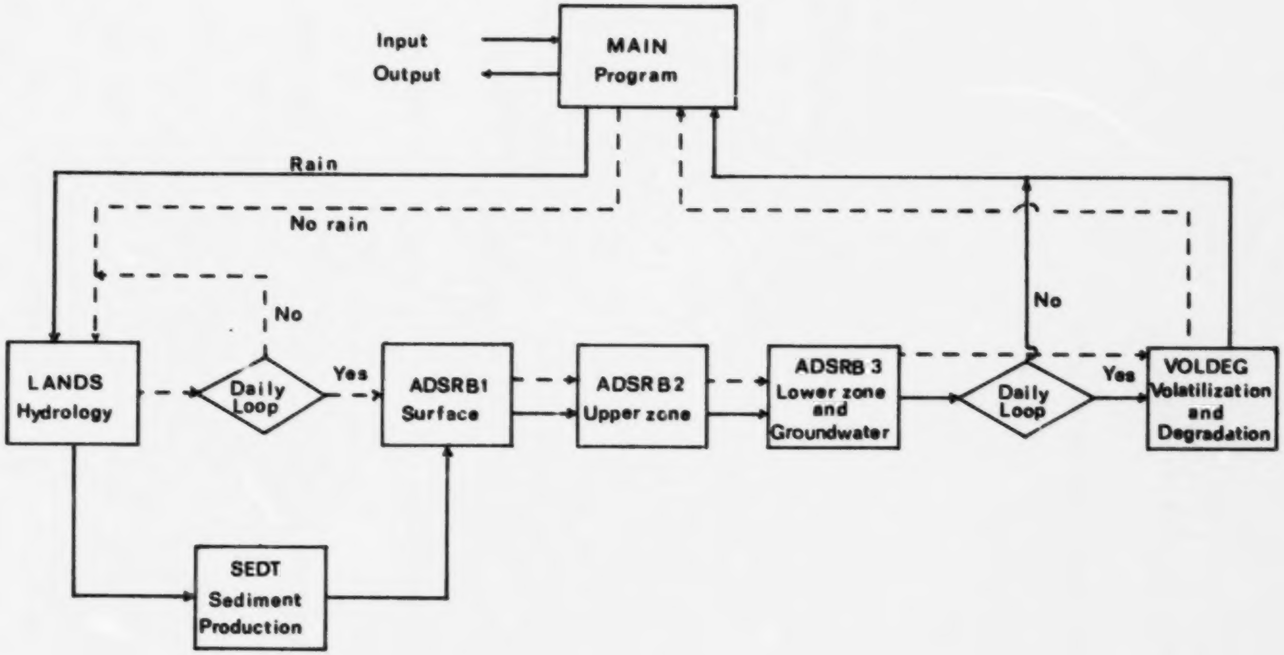

Input
Output
MAIN Program
Rain
No rain
LANDS Hydrology
Daily Loop
No
Yes
ADSRB1 Surface
ADSRB2 Upper zone
ADSRB 3 Lower zone and Groundwater
Daily Loop
No
Yes
VOLDEG Volatilization and Degradation
SEDT Sediment Production

Table 3. SEQUENCE OF INPUT DATA

| | |
|---|---|
| PTR Model Input Parameters | |
| Potential Evapotranspiration | - 1st Year |
| Soil Temperature | - 1st Year |
| Wind Movement | - 1st Year |
| Rainfall | - 1st Year |
| Potential Evapotranspiration | - 2nd Year |
| Soil Temperature | - 2nd Year |
| Wind Movement | - 2nd Year |
| Rainfall | - 2nd Year |
| etc. | |

Model parameters are input in FORTRAN 'namelist' format as shown in Table 4. (Parameter evaluation is discussed in Section 6.4). Daily potential evapotranspiration, average daily soil temperature, and daily wind movement are input under identical format conditions. Daily values are required for each day of simulation. The input format consists of a 31 X 12 matrix, i.e. 12 columns of 31 rows each, representing the 12 months with a maximum of 31 days each. The input format is shown in Table 5. Input daily evapotranspiration and wind movement are in integer form while average daily soil temperature is in real number form correct to the first decimal place. Rainfall data is input in five or fifteen minute intervals according to the format described in Table 6. A complete listing of the input data sequence is included in Appendix B.

## Model Output

A number of options are available for the type of output to be obtained from the Model. The form and substance of the output is controlled by the input parameters HYCAL, PRINT, and UNIT. HYCAL specifies whether the simulation is a calibration run (with or without pesticide simulation), or a production run providing concentrations and amounts of pesticide remaining in the various soil storages. PRINT specifies the interval for the printing of output; daily, hourly, and five or fifteen minute intervals are allowed. In addition, monthly and yearly summaries are provided with all output options. UNIT specifies whether the units of the output will be English, Metric, or both. These three parameters are integers and can only have values of -1, 0, or +1. The values for each option are specified in the portion entitled 'Parameter Evaluation and Model Calibration'.

Since each of the parameters can take on three possible values, the possible output options numbers 27. In practice, only a few combinations are used regularly and will produce specific output forms with any degree of reliability. These combinations and their description and use are as follows:

HYCAL = +1 PRINT= -1 UNIT = -1, 0, +1

> This combination is used primarily for calibration of the LANDS and SEDT subprograms. The output, as shown in Table 7, provides flow and sediment loss values for five or fifteen minute intervals during storm events. Monthly and yearly summaries provide totals so that recorded and simulated volumes can be compared. The input parameter HYMIN specifies the minimum flow for which output is to be printed.

HYCAL = -1 PRINT = -1 UNIT = -1, 0, +1

Table 4. PTR MODEL INPUT PARAMETERS IN 'NAMELIST' FORMAT

```
&HYCL   HYCAL= 0,  HYMIN=0.001, UNIT=-1, INPUT=-1 &END
&PRNT   PRINT= 1 &END
&STRT   BGNDAY=1, BGNMON=7, BGNYR=1972  &END
&ENDD   ENDDAY=15,  ENDMON=2, ENDYR=1973 &END
&TRVL   INTRVL=5  &END
&LND1   UZSN=0.05, LZSN=18.0, INFIL=0.5, INTER=0.7  &END
&LND2   IRC=0.0, NN=0.20, L=160., SS=0.05, A=0.00, UZS=0.05 &END
&LND3   LZS=20.0, SGW=0.0, GWS=0.0, KV=0.0, K24L=1.0, KK24=0.6  &END
&LND4   ICS=0.0, OFS=0.0, IFS=0.0, K24EL=0.0, K3=0.40, EPXM=0.12  &END
&PEST   SSTR=5*13.4, APMODE=0, DEPTH=6.125  &END
&NAME   PNAME='PARAQUAT', WSNAME='P1'  &END
&CRCP   COVMAX=0.60,TIMST=182.,TIMAP=182.,TIMAT=274.,TIMHAR=334. &END
&SMDL   JRER=3.0, KRER=0.09, JSER=1.0, KSER=1.5, SRERI=9.0 &END
&AMDL   CMAX=0.00001,DD=0.0003,BULKD=103.0,K=120.,N=2.,AREA=6.7  &END
&VOL1   DIFC=30.0, TDIFC=30.0, CBDIF=0.11  &END
&VOL2   MOLEWT=335., APFAC=0.0, BPFAC=0.0, WCFAC=1.0 &END
&DEG1   DEGCON=0.0001  &END
```

## Table 5. SAMPLE INPUT AND FORMAT FOR EVAPORATION, TEMPERATURE, AND WIND DATA

| | MONTH | January | February | March | April | May | June | July | August | September | October | November | December | DAY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EVAP72 | 27 | 32 | 96 | 154 | 167 | 185 | 245 | 124 | 145 | 93 | 7 | 30 | 1 |
| | EVAP72 | 27 | 176 | 141 | 49 | 175 | 200 | 262 | 194 | 139 | 116 | 52 | 30 | 2 |
| | EVAP72 | 43 | 410 | 148 | 84 | 198 | 162 | 93 | 219 | 138 | 116 | 61 | 30 | 3 |
| | EVAP72 | 41 | 252 | 118 | 91 | 190 | 285 | 93 | 242 | 238 | 67 | 61 | 34 | 4 |
| | EVAP72 | 41 | 44 | 74 | 105 | 198 | 116 | 234 | 200 | 140 | 45 | 61 | 19 | 5 |
| | EVAP72 | 70 | 63 | 192 | 140 | 251 | 239 | 234 | 89 | 169 | 124 | 107 | 19 | 6 |
| | EVAP72 | 43 | 32 | 163 | 140 | 198 | 231 | 141 | 259 | 92 | 142 | 71 | 14 | 7 |
| | EVAP72 | 119 | 139 | 126 | 154 | 91 | 231 | 141 | 280 | 75 | 144 | 81 | 5 | 8 |
| | EVAP72 | 54 | 57 | 155 | 109 | 122 | 216 | 125 | 203 | 203 | 109 | 29 | 5 | 9 |
| | EVAP72 | 54 | 0 | 148 | 161 | 228 | 162 | 177 | 157 | 106 | 172 | 53 | 5 | 10 |
| | EVAP72 | 54 | 132 | 155 | 70 | 220 | 285 | 177 | 112 | 133 | 97 | 53 | 10 | 11 |
| | EVAP72 | 54 | 63 | 141 | 112 | 175 | 185 | 148 | 132 | 114 | 29 | 53 | 25 | 12 |
| | EVAP72 | 54 | 76 | 215 | 126 | 84 | 200 | 171 | 107 | 113 | 112 | 47 | 16 | 13 |
| | EVAP72 | 59 | 69 | 126 | 147 | 243 | 231 | 158 | 129 | 151 | 82 | 97 | 21 | 14 |
| | EVAP72 | 108 | 189 | 126 | 252 | 205 | 216 | 199 | 164 | 149 | 89 | 68 | 21 | 15 |
| | EVAP72 | 124 | 63 | 89 | 175 | 236 | 200 | 206 | 119 | 159 | 146 | 29 | 21 | 16 |
| | EVAP72 | 103 | 76 | 118 | 280 | 152 | 216 | 67 | 115 | 73 | 114 | 78 | 31 | 17 |
| | EVAP72 | 0 | 151 | 67 | 224 | 144 | 185 | 152 | 156 | 61 | 56 | 78 | 16 | 18 |
| | EVAP72 | 49 | 265 | 74 | 210 | 137 | 131 | 92 | 174 | 129 | 52 | 78 | 47 | 19 |
| | EVAP72 | 11 | 277 | 89 | 168 | 84 | 154 | 272 | 150 | 152 | 156 | 53 | 16 | 20 |
| | EVAP72 | 11 | 69 | 141 | 196 | 219 | 154 | 211 | 204 | 108 | 148 | 20 | 26 | 21 |
| | EVAP72 | 11 | 88 | 178 | 42 | 129 | 377 | 195 | 205 | 112 | 66 | 30 | 26 | 22 |
| | EVAP72 | 65 | 31 | 200 | 189 | 106 | 370 | 227 | 59 | 129 | 86 | 30 | 78 | 23 |
| | EVAP72 | 59 | 38 | 74 | 182 | 167 | 223 | 158 | 133 | 108 | 208 | 30 | 31 | 24 |
| | EVAP72 | 97 | 32 | 111 | 238 | 205 | 216 | 141 | 137 | 84 | 17 | 30 | 42 | 25 |
| | EVAP72 | 97 | 69 | 96 | 112 | 289 | 277 | 141 | 126 | 48 | 90 | 30 | 16 | 26 |
| | EVAP72 | 22 | 101 | 96 | 98 | 243 | 123 | 111 | 123 | 117 | 186 | 71 | 52 | 27 |
| | EVAP72 | 0 | 76 | 81 | 252 | 106 | 39 | 322 | 156 | 141 | 75 | 4 | 104 | 28 |
| | EVAP72 | 27 | 113 | 89 | 63 | 68 | 246 | 99 | 151 | 104 | 58 | 43 | 36 | 29 |
| | EVAP72 | 27 | | 141 | 140 | 53 | 285 | 150 | 187 | 94 | 75 | 102 | 42 | 30 |
| | EVAP72 | 27 | | 74 | | 122 | | 109 | 184 | | 58 | | 62 | 31 |
| COLUMN NUMBER | 7 | 14 | 20 | 26 | 32 | 38 | 44 | 50 | 56 | 62 | 68 | 74 | 80 | |

Notes:
1. Columns 1-7 are ignored. They can be used to identify the data.
2. Blank spaces are interpreted as zero by the Model.
3. Identical format for evaporation, temperature and wind data

## Table 6. PTR MODEL RAINFALL INPUT DATA FORMAT

| Column No. | | Description and Format |
|---|---|---|
| 1 | - | Blank |
| 2-7 | - | Year, Month, Day (e.g., January 1, 1940 is 400101). |
| 8 | - | Card Number - each card represents a 3-hr. period, e.g.<br>Card #1 - Midnight to 3:00 AM<br>#2 - 3:00 AM to 6:00 AM<br>#3 - 6:00 AM to 9:00 AM<br>#8 - 9:00 PM to Midnight<br>All eight cards are required if rain occurred anytime during the day. A card number of 9 signifies that no rain occurred during the entire day, and no other rainfall cards are required for that day. |
| 9-80 | - | Rainfall data (000's of millimeters (00's of inches).<br>15-minute intervals:<br>6 column per each 15-minutes in the 3-hour period of each card. Number must be right justified, i.e. number must end in the 6th column for the 15-minute period.<br>5-minute intervals:<br>2 columns per each 5-minute interval - i.e., the 15-minute period still occupies 6 columns, but it is broken down into 3 5-minute intervals. |
| NOTES | - | 1. Appendix B contains a sample of input data.<br>2. At least one rainfall card is required for each day of simulation.<br>3. Blanks are interpreted as zeros by the Model. Consequently, zeros do not need to be input. |

Table 7. SAMPLE OUTPUT: LANDS AND SEDT CALIBRATION RUN

```
   DATE       TIME        FLOW(CFS - CMS)        SEDIMENT(LBS - KG - GM/L)


JULY      3  20: 5      0.0    0.000         4.45       2.02       24.62
JULY      3  20:10      0.1    0.003        14.58       6.62        6.82
JULY      3  20:15      0.1    0.002         5.99       2.72        3.80
JULY      3  20:20      0.1    0.002         0.92       0.42        0.74
JULY      3  20:25      0.1    0.002         0.0        0.0         0.0
JULY      3  20:30      0.1    0.002         0.0        0.0         0.0
JULY      3  20:35      0.0    0.001         0.0        0.0         0.0
JULY      3  20:40      0.0    0.001         0.0        0.0         0.0
JULY      3  20:45      0.0    0.000         0.0        0.0         0.0
JULY      3  20:50      0.0    0.000         0.0        0.0         0.0
JULY      3  20:55      0.0    0.000         0.0        0.0         0.0
JULY      3  21: 0      0.0    0.000         0.0        0.0         0.0
JULY      3  21: 5      0.0    0.000         0.0        0.0         0.0
JULY      5   0:20      0.0    0.001        16.07       7.30       19.24
JULY      5   0:25      0.5    0.013       159.26      72.30       18.81
JULY      5   0:30      0.7    0.020       201.62      91.54       15.37
JULY      5   0:35      0.5    0.013        88.51      40.19       10.49
JULY      5   0:40      0.3    0.010        46.74      21.22        7.42
JULY      5   0:45      0.2    0.006        19.03       8.64        4.74
JULY      5   0:50      0.1    0.004         5.42       2.46        2.02
JULY      5   0:55      0.1    0.003         0.53       0.24        0.27
JULY      5   1: 0      0.1    0.002         0.0        0.0         0.0
JULY      5   1: 5      0.0    0.001         0.0        0.0         0.0
JULY      5   1:10      0.0    0.001         0.0        0.0         0.0
JULY      5   1:15      0.0    0.001         0.0        0.0         0.0
JULY      5   1:20      0.0    0.001         0.0        0.0         0.0
JULY      5   1:25      0.0    0.000         0.0        0.0         0.0
```

The output from this combination of values is identical to the one above, except that pesticide volumes and concentrations in water and on sediment are also provided. The format for this combination is shown in Table 8.

HYCAL = 0 PRINT = +1 UNIT = -1 or +1

This output format is referred to as a production run. The amount and concentration of pesticide remaining in the various soil storages is provided along with the total volume of pesticide lost by surface runoff, sediment loss, and volatilization and degradation. The format is shown in Table 9. A PRINT value of -1 or 0 allows the investigation of pesticide concentration and movement during short time intervals. However, if PRINT is -1 or 0 for a long simulation run, the volume of output would be enormous. Also if the UNIT option is specified as 0, the volume of output would double because the format in Table 9 would simply be reproduced in metric units during each time interval. Consequently, caution should be used when specifying values of PRINT and UNIT other than shown above for a production run (HYCAL = 0),

The format of the monthly and yearly summaries for calibration and production runs is shown in Tables 10 and 11. The use of a UNIT value of 0 would simply reproduce these tables in metric units, and thus, double the amount of output for the summaries.

## PARAMETER EVALUATION AND CALIBRATION PROCEDURES

Parameter evaluation and calibration are closely related processes. The parameters of the PTR Model are determined for the most part by physical and/or chemical characteristics. Those parameters which are not fixed by natural characteristics are evaluated through calibration. Initial estimates of these parameters are used in the first calibration run of the Model. The comparison of simulated and recorded values provides the basis for re-evaluating the parameter values for subsequent calibration trials. The process is re-iterated until the desired accuracy is achieved.

The following sections discuss the evaluation of the input parameters for each of the subprograms of the PTR Model. Calibration procedures are also discussed as they pertain to the specific subprograms. A complete list of the Model input parameters is provided in Table 12, while Table 13 includes namelist names,

## Table 8. SAMPLE OUTPUT: PESTICIDE CALIBRATION RUN

```
    DATE    TIME     FLOW(CFS - CMS)      SEDIMENT(LBS - KG - GM/L)          PESTICIDE (GM - PPM)
                                                                       WATER                SEDIMENT

  JULY     3  20: 5     0.0   0.000       4.45      2.02     24.62     2.729    33.230     0.032    16.043
  JULY     3  20:10     0.1   0.003      14.58      6.62      6.82     9.446     9.732     0.106    16.036
  JULY     3  20:15     0.1   0.002       5.99      2.72      3.80     3.255     4.553     0.040    14.852
  JULY     3  20:20     0.1   0.002       0.92      0.42      0.74     0.501     0.883     0.006    14.849
  JULY     3  20:25     0.1   0.002       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     3  20:30     0.1   0.002       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     3  20:35     0.0   0.001       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     3  20:40     0.0   0.001       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     3  20:45     0.0   0.000       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     3  20:50     0.0   0.000       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     3  20:55     0.0   0.000       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     3  21: 0     0.0   0.000       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     3  21: 5     0.0   0.000       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     5   0:20     0.0   0.001      16.07      7.30     19.24     1.471     3.876     0.036     4.902
  JULY     5   0:25     0.5   0.013     159.26     72.30     18.81     9.862     2.564     0.278     3.842
  JULY     5   0:30     0.7   0.020     201.62     91.54     15.37    12.505     2.098     0.343     3.744
  JULY     5   0:35     0.5   0.013      88.51     40.19     10.49     5.750     1.500     0.147     3.664
  JULY     5   0:40     0.3   0.010      46.74     21.22      7.42     2.979     1.040     0.078     3.659
  JULY     5   0:45     0.2   0.006      19.03      8.64      4.74     1.230     0.675     0.032     3.656
  JULY     5   0:50     0.1   0.004       5.42      2.46      2.02     0.352     0.288     0.009     3.656
  JULY     5   0:55     0.1   0.003       0.53      0.24      0.27     0.035     0.038     0.001     3.656
  JULY     5   1: 0     0.1   0.002       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     5   1: 5     0.0   0.001       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     5   1:10     0.0   0.001       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     5   1:15     0.0   0.001       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     5   1:20     0.0   0.001       0.0       0.0       0.0      0.0       0.0       0.0       0.0
  JULY     5   1:25     0.0   0.000       0.0       0.0       0.0      0.0       0.0       0.0       0.0
```

### Table 9. SAMPLE OUTPUT: PRODUCTION RUN-DAILY OUTPUT INTERVAL

```
                         24: 0  ON   1   JULY   1972

                              ZONE 1    ZONE 2    ZONE 3    ZONE 4    ZONE 5    TOTAL
WATER, INCHES

   PRECIPITATION              0.0       0.0       0.0       0.0       0.0       0.0

   RUNOFF
      OVERLAND_FLOW           0.0       0.0       0.0       0.0       0.0       0.0
      INTERFLOW               0.0       0.0       0.0       0.0       0.0       0.0
      IMPERVIOUS                                                                0.0
      TOTAL                   0.0       0.0       0.0       0.0       0.0       0.0

   BASE_FLOW                                                                    0.0
   GRDWATER_RECHARGE                                                            0.0

   EVAPORATION
      POTENTIAL               0.245     0.245     0.245     0.245     0.245     0.245
      NET                     0.202     0.202     0.202     0.202     0.202     0.202

   STORAGES
      UPPER_ZONE              0.003     0.003     0.003     0.003     0.003     0.003
      LOWER_ZONE             19.845    19.845    19.845    19.845    19.845    19.845
      GROUNDWATER             0.0       0.0       0.0       0.0       0.0       0.0
      INTERCEPTION            0.0       0.0       0.0       0.0       0.0       0.0
      OVERLAND_FLOW           0.0       0.0       0.0       0.0       0.0       0.0
      INTERFLOW               0.0       0.0       0.0       0.0       0.0       0.0

   WATER_BALANCE=  0.0

 SEDIMENT, TONS
   TOTAL SEDIMENT LOSS        0.0       0.0       0.0       0.0       0.0       0.0
   FINES DEPOSIT              1.800     1.800     1.800     1.800     1.800     9.000
   IMPERVIOUS EROSION                                                           0.0
SURFACE LAYER PESTICIDE

  PESTICIDE, LBS              0.161     0.161     0.161     0.161     0.161     0.804
    ADSORBED                  0.161     0.161     0.161     0.161     0.161     0.804
    CRYSTALLINE               0.0       0.0       0.0       0.0       0.0       0.0
    DISSOLVED                 0.0       0.0       0.0       0.0       0.0       0.0

  PESTICIDE, PPM              2.568     2.568     2.568     2.568     2.568     2.568
    ADSORBED                  2.568     2.568     2.568     2.568     2.568     2.568
    CRYSTALLINE               0.0       0.0       0.0       0.0       0.0       0.0
    DISSOLVED                 0.0       0.0       0.0       0.0       0.0       0.0

  REMOVAL, LBS                0.0       0.0       0.0       0.0       0.0       0.0
    SEDIMENT                  0.0       0.0       0.0       0.0       0.0       0.0
    OVERLAND FLOW             0.0       0.0       0.0       0.0       0.0       0.0
    PERCOLATION               0.0       0.0       0.0       0.0       0.0       0.0
UPPER ZONE LAYER PESTICIDE

  PESTICIDE, LBS              3.859     3.859     3.859     3.859     3.859    19.296
    ADSORBED                  3.858     3.858     3.858     3.858     3.858    19.288
    CRYSTALLINE               0.0       0.0       0.0       0.0       0.0       0.0
    DISSOLVED                 0.002     0.002     0.002     0.002     0.002     0.008
```

## Table 9. (continued)

```
   PESTICIDE, PPM          4.335    4.335    4.335    4.335    4.335    4.335
      ADSORBED             2.566    2.566    2.566    2.566    2.566    2.566
      CRYSTALLINE          0.0      0.0      0.0      0.0      0.0      0.0
      DISSOLVED            1.768    1.768    1.768    1.768    1.768    1.768

   REMOVAL, LBS            0.0      0.0      0.0      0.0      0.0      0.0
      INTERFLOW            0.0      0.0      0.0      0.0      0.0      0.0
      PERCOLATION          0.0      0.0      0.0      0.0      0.0      0.0

LOWER ZONE LAYER PESTICIDE

   PESTICIDE, LBS                                                     0.0
      ADSORBED                                                        0.0
      CRYSTALLINE                                                     0.0
      DISSOLVED                                                       0.0

   PESTICIDE, PPM
      ADSORBED                                                        C.0
      CRYSTALLINE                                                     0.0
      DISSOLVED                                                       0.0

   REMOVAL, LBS                                                       0.0
      PERCOLATION                                                     0.0

GROUNDWATER LAYER PESTICIDE

   PESTICIDE, LBS                                                     0.0
      ADSORBED                                                        0.0
      CRYSTALLINE                                                     C.0
      DISSOLVED                                                       0.0

PESTICIDE VOLATILIZATION LOSS, LBS.
   TOTAL                                                              0.540
   FROM SURFACE                                                       0.0
   FROM UPPER ZONE                                                    0.540

PESTICIDE DEGRADATION LOSS, LBS.
   TOTAL                                                              0.219
   FROM SURFACE                                                       0.009
   FROM UPPER ZONE                                                    0.210
   FROM LOWER ZONE                                                    0.0
```

Table 10. SAMPLE OUTPUT: CALIBRATION RUN - MONTHLY SUMMARY

```
                       SUMMARY FOR MONTH OF    JULY    1972

                             ZONE 1     ZONE 2     ZONE 3     ZONE 4     ZONE 5      TOTAL
WATER, INCHES

   PRECIPITATION             2.190      2.190      2.190      2.190      2.190       2.190

   RUNOFF
      OVERLAND_FLOW          0.834      0.519      0.307      0.177      0.094       0.386
      INTERFLOW              0.117      0.154      0.145      0.124      0.146       0.137
      IMPEPVIOUS                                                                     0.0
      TOTAL                  0.952      0.673      0.452      0.301      0.240       0.523

   BASE_FLOW                                                                         0.0
   GROWATER_RECHARGE                                                                 0.573

   EVAPORATION
      POTENTIAL              5.259      5.259      5.259      5.259      5.259       5.259
      NET                    3.574      3.574      3.574      3.574      3.574       3.574

   STORAGES
      UPPER_ZONE             0.096      0.095      0.095      0.095      0.094       0.096
      LOWEP_ZONE            17.432     17.432     17.432     17.432     17.432      17.432
      GROUNDWATER            0.0        0.0        0.0        0.0        0.0         0.0
      INTERCEPTION           0.039      0.039      0.039      0.039      0.039       0.039
      OVERLAND_FLOW          0.0        0.0        0.0        0.0        0.0         0.0
      INTERFLOW              0.0        0.0        0.0        0.0        0.0         0.0

   WATER_BALANCE=  0.0006

SEDIMENT, TONS
   TOTAL SEDIMENT LOSS       2.068      1.642      1.161      0.731      0.416       6.019
   FINES DEPOSIT             0.633      1.058      1.539      1.970      2.284       7.483
   IMPERVIOUS EROSION                                                                0.0

PESTICIDE REMOVAL, LBS.      0.148      0.042      0.016      0.008      0.005       0.220
   OVERLAND FLOW REMOVAL     0.143      0.040      0.015      0.008      0.004       0.210
   SEDIMENT REMOVAL          0.005      0.002      0.001      0.001      0.000       0.009
   INTERFLOW REMOVAL         0.0        0.0        0.0        0.0        0.0         0.0

PESTICIDE VOLATILIZATION LOSS, LBS.
   TOTAL                                                                             0.0
   FROM SURFACE                                                                      0.0
   FROM UPPER ZONE                                                                   0.0

PESTICIDE DEGRADATION LOSS, LBS.
   TOTAL                                                                             5.756
   FROM SURFACE                                                                      0.751
   FROM UPPER ZONE                                                                   5.005
   FROM LOWER ZONE                                                                   0.000

   PESTICIDE_BALANCE= -0.0033
```

Table 11. SAMPLE OUTPUT: PRODUCTION RUN - MONTHLY SUMMARY

```
                         SUMMARY FOR MONTH OF   JULY   1972

                              ZONE 1    ZONE 2    ZONE 3    ZONE 4    ZONE 5    TOTAL
 WATER, INCHES

    PRECIPITATION              2.190     2.190     2.190     2.190     2.190     2.190

    RUNOFF
       OVERLAND_FLOW           0.834     0.519     0.307     0.177     0.094     0.386
       INTERFLOW               0.117     0.154     0.145     0.124     0.146     0.137
       IMPERVIOUS                                                                0.0
       TOTAL                   0.952     0.673     0.452     0.301     0.243     0.523

    BASE_FLOW                                                                    0.0
    GRDWATER_RECHARGE                                                            0.573

    EVAPORATION
       POTENTIAL               5.259     5.259     5.259     5.259     5.259     5.259
       NET                     3.574     3.574     3.574     3.574     3.574     3.574

    STORAGES
       UPPER_ZONE              0.096     0.095     0.095     0.095     0.094     0.096
       LOWER_ZONE             17.432    17.432    17.432    17.432    17.432    17.432
       GROUNDWATER             0.0       0.0       0.0       0.0       0.0       0.0
       INTERCEPTION            0.039     0.039     0.039     0.039     0.039     0.039
       OVERLAND_FLOW           0.0       0.0       0.0       0.0       0.0       0.0
       INTERFLOW               0.0       0.0       0.0       0.0       0.0       0.0

    WATER_BALANCE=  0.0006

  SEDIMENT, TONS
    TOTAL SEDIMENT LOSS        2.066     1.642     1.161     0.731     0.416     6.017
    FINES DEPOSIT              0.634     1.058     1.539     1.970     2.284     7.485
    IMPERVIOUS EROSION                                                           0.0

PESTICIDE, POUNDS

  SURFACE LAYER                 0.021     0.020     0.019     0.019     0.018     0.097
     ADSORBED                   0.021     0.020     0.019     0.019     0.019     0.098
     CRYSTALLINE                0.0       0.0       0.0       0.0       0.0       0.0
     DISSOLVED                  0.0       0.0       0.0       0.0       0.0       0.0

  UPPER ZONE LAYER              2.699     2.807     2.833     2.841     2.845    14.024
     ADSORBED                   2.719     2.826     2.852     2.861     2.865    14.124
     CRYSTALLINE                0.0       0.0       0.0       0.0       0.0       0.0
     DISSOLVED                  0.010     0.011     0.011     0.011     0.011     0.055

  LOWER ZONE LAYER                                                                0.000
     ADSORBED                                                                     0.0
     CRYSTALLINE                                                                  0.0
     DISSOLVED                                                                    0.0

  GROUNDWATER LAYER                                                               0.0
     ADSORBED                                                                     0.0
     CRYSTALLINE                                                                  0.0
     DISSOLVED                                                                    0.0

  PESTICIDE REMOVAL, LBS.     0.148     0.042     0.016     0.008     0.005     0.220
     OVERLAND FLOW REMOVAL    0.143     0.040     0.015     0.008     0.004     0.210
     SEDIMENT REMOVAL         0.005     0.002     0.001     0.001     0.000     0.009
     INTERFLOW REMOVAL        0.0       0.0       0.0       0.0       0.0       0.0

  PESTICIDE VOLATILIZATION LOSS, LBS.
     TOTAL                                                                     0.0
     FROM SURFACE                                                              0.0
     FROM UPPER ZONE                                                           0.0

  PESTICIDE DEGRADATION LOSS, LBS.
     TOTAL                                                                     5.756
     FROM SURFACE                                                              0.751
     FROM UPPER ZONE                                                           5.005
     FROM LOWER ZONE                                                           0.000

     PESTICIDE_BALANCE= -0.0033
```

## Table 12. PTR MODEL INPUT PARAMETER DESCRIPTION

HYCAL: Indicates mode of operation
  -1 - Calibration run with pesticide simulation
  0 - Production run
  +1 - Calibration run without pesticide simulation

HYMIN: Minimum flow for printing output during a time interval.

INPUT: Input units; English (-1), Metric (1).

UNIT: Output units; English (-1), Metric (1), Both (0).

PRINT: Denotes frequency of printing output; Each interval (-1), each hour (0), or each day (1).

BGNDAY, BGNMON, BGNYR: Date simulation begins; Day, month, year

ENDDAY, ENDMON, ENDYR: Date simulation ends; Day, month, year.

INTRVL: Time interval of operation ( 5 or 15 minutes).

UZSN: Nominal upper zone storage.

LZSN: Nominal lower zone storage.

INFIL: Index infiltration rate.

INTER: Interflow parameter, alters runoff timing.

IRC: Interflow recession rate.

NN: Manning's n for overland flow.

L: Length of overland flow to channel.

SS: Average overland flow slope.

A: Fraction of area that is impervious.

UZS: Initial upper zone storage.

LZS: Initial lower zone storage.

SGW: Initial groundwater storage.

GWS: Initial slope of the groundwater table.

KV: Parameter to allow variable recession rate for groundwater discharge.

K24L: Fraction of groundwater recharge percolating to deep groundwater.

KK24: Groundwater recession rate.

ICS: Initial interception storage.

OFS: Initial overland flow storage.

IFS: Initial interflow storage.

K24EL: Fraction of watershed area where groundwater is within reach of vegetation.

K3: Index to actual evaporation.

EPXM: Maximum interception storage.

PNAME: Pesticide name (8 characters, maximum).

WSNAME: Watershed name (8 characters, maximum).

SSTR: Total pesticide application (on zonal basis).

APMCDE: Mode of application; surface applied (0), soil incorporated (1).

DEPTH: Depth of soil incorporation and/or upper zone depth.

COVMAX: Maximum surface area covered by fully matured vegetation.

TIMST: Time simulation starts (Julian day, i.e., day of the year (e.g., January 1 is 1, December 31, is 365 or 366, etc.).

TIMAP: Time of pesticide application (Julian day).

TIMAT: Time of crop maturity (Julian day).

TIMHAR: Time of harvest (Julian day).

JRER: Exponent of rainfall intensity in soil splash equation.

KRER: Coefficient in soil splash equation.

JSER: Exponent of overland flow in surface scour equation.

KSER: Coefficient in surface scour equation.

SRERI: Initial fines deposit.

CMAX: Maximum solubility of pesticide in water.

DD: Permanently fixed capacity (lb pesticide/lb soil).

BULKD: Bulk density of soil.

K: Coefficient in Freundlich adsorption curve.

N: Exponent in Freundlich adsorption curve.

AREA: Watershed area.

DIFC: Pesticide diffusion coefficient.

TDIFC: Temperature at which DIFC was measured.

CBDIFC: Exponent of temperature correction for diffusion coefficient.

MOLEWT: Molecular weight of pesticide.

APFAC, BPFAC: Constants for temperature adjustment of pesticide vapor pressure.

WCFAC: Wind calibration factor.

DEGCON: First order daily pesticide decay rate.

Table 13. PTR MODEL INPUT PARAMETER ATTRIBUTES

| Namelist Name | Parameter Name | Type | English* Units | Metric* Units |
|---|---|---|---|---|
| HYCL | HYCAL | Integer | - | - |
| | HYMIN | Real | Cubic feet per second (CFS) | Cubic meters per second (CMS) |
| | UNIT | Integer | - | - |
| | INPUT | Integer | - | - |
| PRNT | PRINT | Integer | - | - |
| STRT | BGNDAY | Integer | - | - |
| | BGNMON | Integer | - | - |
| | BGNYR | Integer | - | - |
| ENDD | ENDDAY | Integer | - | - |
| | ENDMON | Integer | - | - |
| | ENDYR | Integer | - | - |
| TRVL | INTRVL | Integer | Minutes (min) | Minutes (min) |
| LND1 | UZSN | Real | Inches (in) | Millimeters (mm) |
| | LZSN | Real | Inches (in) | Millimeters (mm) |
| | INFIL | Real | Inches per hour (in/hr) | Millimeters per hour (mm/hr) |
| | INTER | Real | - | - |
| LND2 | IRC | Real | - | - |
| | NN | Real | - | - |
| | L | Real | feet (ft) | meters (m) |
| | SS | Real | - | - |
| | A | Real | - | - |
| | UZS | Real | inches (in) | millimeters (mm) |
| LND4 | LZS | Real | inches(in) | millimeters (mm) |
| | SGW | Real | inches(in) | millimeters (mm) |
| | GWS | Real | - | - |
| | KV | Real | - | - |
| | K24L | Real | - | - |
| | KK24 | Real | - | - |
| LND4 | ICS | Real | inches(in) | millimeters (mm) |
| | OFS | Real | inches(in) | millimeters (mm) |
| | IFS | Real | inches(in) | millimeters (mm) |

---

* - dashes denote dimensionless values.

|  |  |  |  |  |
|---|---|---|---|---|
|  | K24EL | Real | - | - |
|  | K3 | Real | - | - |
|  | EPXM | Real | inches(in) | millimeters (mm) |
| PEST | SSTR | Real | pounds (lb) | kilograms (kg) |
|  | APMODE | Integer | - | - |
|  | DEPTH | Real | inches(in) | millimeters (mm) |
| NAME | PNAME | Real | - | - |
|  | WSNAME | Real | - | - |
| CROP | COVMAX | Real | - | - |
|  | TIMST | Real | - | - |
|  | TIMAP | Real | - | - |
|  | TIMAT | Real | - | - |
|  | TIMHAR | Real | - | - |
| SMDL | JRER | Real | - | - |
|  | KRER | Real | - | - |
|  | JSER | Real | - | - |
|  | KSER | Real | - | - |
|  | SKERI | Real | tons | tonnes (t) |
| AMDL | CMAX | Real | pounds per pound (lb/lb) | kilograms per kilogram (kg/kg) |
|  | DD | Real | pound pesticide per pound soil (lb/lb) | kilogram pesticide per kilogram soil (kg/kg) |
|  | BULKD | Real | pounds per cubic foot (lb/ft3) | grams per cubic centimeter (g/cc) |
|  | K | Real | - | - |
|  | N | Real | - | - |
|  | AREA | Real | acres (ac) | hectares (ha) |
| VOL1 | DIFC | Real |  | millimeters square per week ($mm^2/wk$)+ |
|  | TDIFC | Real |  | degrees Celcius (°C)+ |
|  | CBDIF | Real | - | - |
| VOL2 | MOLEWT | Real |  | grams per mole (g/mole)+ |
|  | APFAC | Real | - | - |
|  | BPFAC | Real | - | - |
|  | WCFAC | Real | - | - |
| DEG1 | DEGCON | Real | - | - |

+only allowable input units

## Operational Parameters

The operational parameters are employed largely in the MAIN subprogram, and are involved with real-time and input/output operations of the Model. These parameters are included in the namelists HYCL, PRNT, STRT, ENDD, and TRVL as shown in Table 13. They are essentially self-explanatory, and are not involved in calibration.

## LANDS Parameters

The LANDS subprogram parameters are included in namelists LND1, LND2, LND3, and LND4. The majority of the LANDS parameters are explained in detail in Appendix A. In fact, the only parameters not described in Appendix A are the initial storage parameters UZS, LZS, SGW, GWS, ICS, OFS, and IFS, which are defined in Table 12. Except for UZS and LZS, the remaining storage parameters are generally set to zero. Since these parameters refer to initial conditions, their effect on long-term simulation is negligible. The initial storages UZS and LZS are directly related to the surface response of the watershed during the initial months of simulation. Consequently their values have a direct impact on surface runoff for three to six months after simulation begins. Their effect in the long term is also negligible.

The values for UZS and LZS are generally close to their nominal values, UZSN and LZSN. If simulation begins in a wet season their values are either equal to or greater than the nominal values. On the other hand, the initial storages will be less than nominal if simulation begins in a dry season.

Calibration of the LANDS subprogram initially involves the adjustment of the parameters so that recorded annual and monthly runoff volumes are simulated as closely as possible. Once the volume simulation is attained, simulated and recorded storm hydrographs are compared. Peak flow rates, timing, and hydrograph shape are the major characteristics investigated. Appendix A contains numerous suggestions on the effects of varying the different parameters. The interactions of the 15 major parameters (excluding moisture storages) are quite complex. A detailed reading of Appendix A plus a number of calibration trials should provide the user with a certain 'feel' for the parameters involved.

## Watershed and Pesticide Application Parameters

This group of parameters is used throughout the PTR Model for the special purposes of pesticide application nomenclature, and crop cover. Calibration does not involve these parameters as they are completely defined.

The namelist, PEST, includes parameters which apply to the amount of pesticide applied (SSTR), the method of application (APMODE), and the depth of the upper zone and/or the soil-incorporated pesticide (DEPTH). SSTR is programmed to allow an areal variation in application across the five surface zones of the watershed. Thus, a uniform application of 100 pounds can be specified either as 'SSTR = 20., 20., 20., 20., 20.' or 'SSTR = 5 * 20.' , within the namelist format. The DEPTH parameter specifies both the bottom depth of the upper zone and of the soil-incorporated pesticides. Thus, a uniform pesticide concentration throughout the upper zone is assumed for soil-incorporated pesticides, and total upper zone moisture (UZS) is employed when determining pesticide loss by interflow and percolation.

The namelist CROP includes parameters which define the variable interception of rainfall by the crop canopy over the growing season. COVMAX defines the maximum percent of the watershed area covered by the crop canopy when fully matured. The parameters TIMST, TIMAP, TIMAT, and TIMHAR define the first day of simulation, and the days of application, crop maturity, and harvesting, respectively. The MAIN program, which monitors the passage of real time, provides a linear increase in crop cover from TIMAP to TIMAT up to a maximum value defined by COVMAX. Crop cover remains at COVMAX until harvesting time when it is returned to a value of zero. The crop canopy affects both the interception of rainfall in LANDS, and the soil splash production of fines in SEDT.

## SEDT Parameters

The SEDT parameters are included within the namelist SMDL. The only experience with the SEDT parameters, other than the subject research effort, has been presented by Negev [19] . His work was used as a guide in calibrating the sediment loss model to the experimental watersheds. Much additional research is needed into the sensitivity of the SEDT parameters and their relationship to soil properties. The values obtained from calibration on the experimental watersheds provides some guidance for use of the model on watersheds with similar characteristics.

Calibration procedures for SEDT are similar to those for LANDS. Recorded annual and monthly volumes are compared to simulated values. The soil splash parameters, JRER and KRER, appear to have the most significant impact on the seasonal distribution of sediment loss. Increasing JRER provides a greater relative impact to the high-intensity summer storms than the low-intensity long duration winter storms. KRER and SRERI, the initial surface storage of soil fines, were adjusted so that the surface fines deposit did not get progressively larger or smaller throughout the simulation period. The surface scour and pick-up parameters, JSER and KSER, have a direct effect on sediment loss concentrations during the storm events. Adjustment of both JSER and KSER is required in order to reproduce the rate of sediment loss recorded during storm events.

In summary, the above guidelines are the result of calibration trials on the experimental watersheds in this research effort.

Application on other watersheds will require separate calibration trials, and caution should be used when transferring calibrated values from one watershed to another.

## Pesticide Adsorption-Desorption and VOLDEG Parameters

The parameters in this group need to be determined largely from laboratory experiments. Consequently very little adjustment during calibration is justifiable. Some variation in parameters for natural environmental conditions different from laboratory conditions is expected. However, this should be minimal for the parameters involved.

The pesticide adsorption-desorption parameters used in subprograms ADSRB1, ADSRB2, and ADSRB3 are contained in namelist AMDL. These are described sufficiently in Tables 12 and 13. CMAX and BULKD can be obtained from experimental results or published reports. DD, K, and N must be evaluated by an experimental determination of the adsorption isotherm for the specific pesticide and soil system. DD would be the intercept at zero solution concentration, while K and N describe the isotherm in terms of the Freundlich equation ( Section V).

The namelists, VOL1 and VOL2, include the parameters for surface and soil-incorporated pesticide volatilization. The majority of these parameters must also be determined from laboratory experiments or published reports. For soil-incorporated pesticides, the parameters DIFC, TDIFC, and CBDIF define the temperature dependence of the total diffusion coefficient as described in Section III. For surface applied pesticides, APFAC and BPFAC define the temperature dependence of the pesticide vapor pressure (Section III ), while WCFAC provides a calibration tool for the effect of wind movement on volatilization. Since no data was available for calibration or verification of these models, they were not operated during calibration trials of the PTR Model. To bypass the volatilization models, DIFC (soil-incorporated), and both APFAC and BPFAC (surface-applied) are set equal to zero.

The namelist, DEG1 contains the soil degradation parameter, DEGCON, which defines the daily first-order degradation rate for the pesticide. DEGCON was calculated by applying a first-order degradation to the initial application, and determining that rate which would reproduce the amount of pesticide remaining on the watershed as determined by the October 30 sampling analysis. Thus, the value is purely empirical and is used to allow a realistic reduction in pesticide concentration on the watershed as a result of degradation.

## Conclusion

Calibration initially involves only the LANDS and SEDT subprograms (HYCAL= +1) until an adequate simulation of runoff and sediment loss is obtained. Then pesticide simulation is included (HYCAL= -1) and a number of trials may be run for minute adjustments in the pesticide parameters. Finally production runs (HYCAL = 0) are performed to obtain pesticide concentrations and amounts remaining on the land surface.

In summary, efficient calibration and parameter evaluation requires a thorough knowledge of the operation of the PTR Model. This is best acquired through repeated use of the Model and its components under varying climatic and edaphic conditions. Additional experience on use of the model is necessary.

The parameter values for the final trials on the P1 watershed are shown in Table 14. Separate values for Paraquat and Enide are also included. Section VIII presents the results obtained from application of the PTR Model to the experimental watersheds.

Table 14. PARAMETER VALUES AND INITIAL CONDITIONS
FROM P1 CALIBRATION
(English Units)

| Parameter | Value | Parameter | Value | Parameter | Value |
|---|---|---|---|---|---|
| UZSN | 0.05 | COVMAX | 0.60 | DIFC | 0.0* |
| LSZN | 18.0 | TIMST | 182.0 | TDIFC | 1.0* |
| INFIL | 0.5 | TIMAP | 182.0 | CBDIF | 1.0* |
| INTER | 0.7 | TIMAT | 274.0 | MOLEWT | 0.0* |
| IRC | 0.0 | TIMHAR | 334.0 | APFAC | 0.0* |
| NN | 0.20 | JRER | 3.0 | BPFAC | 0.0* |
| L | 160.0 | KRER | 0.09 | WCRAC | 1.0* |
| SS | 0.05 | JSER | 1.0 | | |
| A | 0.0 | KSER | 1.5 | Initial Conditions | Value |
| KV | 0.0 | CMAX (P) | 0.00001 | UZS | 0.05 |
| K24L | 1.0 | (D) | 0.00026 | LZS | 20.0 |
| KK24 | 0.6 | DD (P) | 0.0003 | SGW | 0.0 |
| K24EL | 0.0 | (D) | 0.0 | GWS | 0.0 |
| K3 | 0.40 | BULKD | 103.0 | ICS | 0.0 |
| EPXM | 0.12 | K (P) | 120.0 | OFS | 0.0 |
| APMODE | 0.0 | (D) | 1.8 | IFS | 0.0 |
| DEPTH | 6.125 | N (P) | 2.0 | SRERI | 9.0 |
| DEGCON (P) | 0.0001 | (D) | 1.6 | SSTR (P) | 5x13.4 |
| (D) | 0.0109 | AREA | 6.7 | (D) | 5x4.02 |

(P) - Paraquat
(D) - Diphenamid
* - These values are input to bypass the volatilization models.

## SECTION VII

## EXPERIMENTAL PROGRAM* AND MODELING METHODOLOGY

### EXPERIMENTAL PROGRAM

The PTR Model development was conducted in support of an experimental data gathering program at the U. S. Environmental Protection Agency's Southeast Environmental Research Laboratory (SERL) in Athens, Georgia. The program was a joint effort between the SERL and the U. S. Agricultural Research Service's Southern Piedmont Conservation Research Center (ARS-SPCRC) in Watkinsville, Georgia. Experimental watersheds at the SPCRC in Watkinsville (Figure 10) were instrumented for the continuous monitoring and sampling of runoff and sediment during the 1972 growing season. Samples collected during storm events were analyzed for pesticide concentrations at the SERL laboratories. A gas-liquid chromatograph was used in the pesticide analysis.

The watersheds are located on the Piedmont Plateau of the Southeastern U. S. in Oconee County, Georgia. The soils classification is a Cecil sandy loam with high acidity and clay content and low organic matter content. The moderate slopes, two to six percent, provide a slight to moderate erosion hazard, while surface runoff, infiltration and water capacity are considered moderate.

The 1972 program included two large watersheds (P1 - 2.7 ha and P3 - 1.2 ha), two small runoff plots (SP1 (9x22 meters) and SP3 (26x39 meters)), and 12 20x30 ft. (6x9 meters) attenuation plots (Figure 10). The experimental areas were planted with soybeans for the 1972 growing season. The herbicides, paraquat (1,1'-dimethyl-4,4'-bipyridinium ion), diphenamid (N,N-dimethyl-2,2-diphenylacetamide), and trifluralin ($\alpha,\alpha,\alpha$-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine) were applied at ten, three and one pound per acre (11.2, 3.4, and 1.1) kg/ha, respectively. These herbicides were chosen to facilitate the study of pesticide transport in the adsorbed phase (paraquat) in the dissolved phase (diphenamid), and discrete particles (trifluralin). Runoff and sediment samples were automatically collected during storm events at short time intervals, and refrigerated on-site for later analysis at the SERL. Core samples were taken and analyzed

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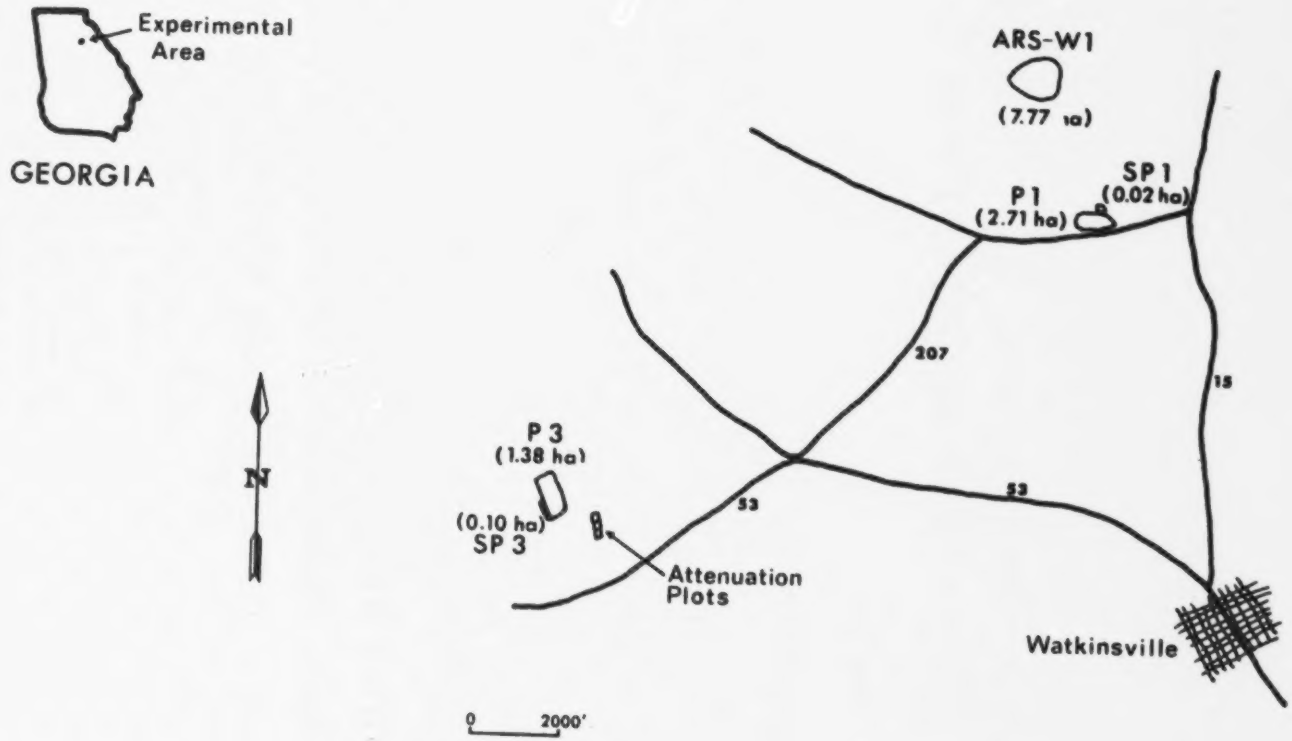
* Contact Dr. George W. Bailey at the SERL, Athens, Georgia for further details on the continuing experimental program.

Figure 10. Location of experimental watersheds


Experimental Area
GEORGIA
ARS-W1
(7.77 ha)
P 1
(2.71 ha)
SP 1
(0.02 ha)
207
15
53
53
N
P 3
(1.38 ha)
(0.10 ha)
SP 3
Attenuation Plots
Watkinsville
0
2000'

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

immediately after pesticide application and periodically during the growing season to determine the extent of vertical movement and the remaining volumes of the applied pesticides. Recording rain gages were established at each major watershed, and a weather station was set up at the attenuation plots to record air temperature, pan evaporation, and wind data. Also, the attenuation plots were instrumented to record soil moisture and temperature at various soil depths, wind velocity and direction, solar intensity, net radiation, air temperature, and relative humidity at different heights above the soil surface. This data was automatically recorded on magnetic tape by a PDP-8 computer. The extensive data gathered during the program is to be included in the EPA STORET data system, available to interested agencies.

## MODELING METHODOLOGY

Hydrocomp's support of the experimental program involved review of the data gathering procedures and development of the PTR Model to simulate the recorded loss of pesticide from the watersheds. The guiding philosophy in Hydrocomp's modeling effort was to develop a model capable of:

(1) Simulating the pesticide lost from, and remaining on the land surface.

(2) Reproducing the gross movement of pesticide within the soil profile.

(3) Performing a mass-balance of the applied pesticide.

(4) General application in various regions of the country.

(5) Performing continuously for up to 1 or 2 years at reasonable computer cost.

Although the existing Model is not capable of completely satisfying all of these goals, the basic framework of the Model is designed to perform these functions.

The modeling approach was on an area-wide watershed basis, with an attempt to 'piggyback' the pesticide onto the movement of water and sediment from the land surface. Detailed consideration was not directed to the microscale movement and minute interactions of the pesticide within numerous layers of the soil profile. The reasons for this approach are three fold: first, variations in soil characteristics, sediment movement, and pesticide movement across a watershed are too complex to simulate in detail; second, a detailed model would be so watershed-dependent as to lose its general applicability; third, a useful model must employ only parameters and constants which are generally available with reasonable effort for watersheds to which it is to be applied.

With this approach, the modeling effort was concerned largely with the data collected on the larger watersheds, P1 and P3. Data from SP1 and SP3 was investigated for comparison purposes, and hydrometeorological data was provided by the instrumentation at the attenuation plots. Also, historical rainfall and runoff data for the period 1940-44 for the ARS W1 (7.77 ha ) watershed at Watkinsville was provided by the SPCRC for calibration purposes. Calibration for runoff and sediment was performed on the P1 watersheds. Results from simulation on the W1 watershed with the calibrated parameters were used to check the validity of the P1 calibration. Both the P1 and P3 watersheds were run with the calibrated parameters to determine pesticide loss. Since P3 is a terraced watershed, some deviation was expected from recorded values of runoff, sediment and pesticide loss, because the parameters were calibrated on the P1 non-terraced watershed. The results of the simulation runs and problems encountered in calibration are discussed in Section VIII.

# SECTION VIII

# PTR MODEL RESULTS AND DISCUSSIONS

## GENERAL

As in most research endeavors, the results obtained from the PTR Model development and testing were both good and bad. A number of questions have been answered but many more have been raised. The initial portion of this section discusses calibration trials on P1 and W1, and presents results of pesticide trials on P1. Analytical problems in obtaining an adsorption isotherm for trifluralin, prevented simulation of that herbicide. The results of runoff, sediment, and pesticide trials on the P3 watershed using the parameters calibrated on P1 are provided. Certain inconsistencies in the recorded data are also discussed. Finally, a general discussion of the simulation results is presented.

## P1 WATERSHED RESULTS

### Calibration - Runoff and Sediment Loss

Seven and one-half months of continuous rainfall, runoff, sediment, and pesticide residue data provided the basis for calibration of the P1 watershed. During this period, only four significant runoff-producing events occurred, three of which were within one and one-half months from the beginning of the simulation period. Generally, calibration is performed continuously for a minimum of about two years. The reasons for this are two-fold: first, two years of data will likely include both dry and wet periods so that the hydrologic response can be calibrated under a variety of soil moisture conditions; secondly, a long period of record will overcome the effects of initial soil moisture and surface sediment conditions which can have a significant effect for three to six months into the calibration period.

The available data for the P1 calibration violated both of the above conditions. The lack of a long period of data could not be corrected. Initially, the starting soil moisture conditions were obtained by simulating the three month period prior to the July 1 starting date. Rainfall data from the Athens Weather Service Office was used. Because of the variability of thunderstorms in Georgia and resulting soil moisture conditions, the results of the three-month simulation yielded starting soil moisture conditions much lower than expected. Consequently, the values of initial soil moisture were adjusted in the final calibration trials in order to reflect the recorded runoff volumes.

Table 14 in Section VI presented the calibration parameters of the P1 watershed. The simulated and recorded monthly volumes of runoff and sediment are shown in Figure 11 and Table 15, along with recorded rainfall values. Simulated runoff volumes are generally within 10 percent of recorded values. The error in the simulated runoff for January is partially the result of the January 7 - 8 storm during which snowmelt occurred. Also, rainfall data on the storm of January 21-22 was received too late to be included in the simulation. This would have an effect on antecedent soil moisture conditions. Simulated sediment volumes closely follow the recorded values except for the month of December.

Rainfall intensity, and recorded and simulated runoff and sediment concentrations for the four major storm events during the calibration period are shown in Figures 12, 13, 14, and 15. Simulated peak runoff and sediment concentrations are reasonably close to recorded values. The high intensity, short duration summer storms (Figures 12, 13, 14) appear to be more accurately simulated than the long low-intensity winter storm (Figure 15). Note the time variation between the summer and winter storms. For the summer storms, peak runoff occurs within five minutes of peak rainfall intensity. Also, peak sediment concentration occurs immediately prior to peak runoff. For the winter storm, the recorded hydrologic response is somewhat sluggish with peak runoff occurring up to 15 minutes following peak rainfall intensity. Also, detailed sediment concentrations are lacking at critical moments during the winter storm. One would expect the peak sediment concentration to occur between 22:30 and 22:10. Unfortunately no sediment values were recorded during this time period.

It should be noted that a weir pond formed in front of the P1 gage during runoff events. This pond likely had a significant effect on recorded runoff and sediment loss, and the resulting pesticide loss. The storage of water provided by the pond would tend to delay the rising portion of storm hydrographs and extend the recession side of the hydrograph. The recorded peak flow would be less than that which actually occurred from the watershed. The estimated volume of the P1 weir pond appears to be sufficient to change the simulated hydrograph of the July 28 storm (Figure 12) to closely approximate the recorded hydrograph.

The effect of the pond on sediment loss would be to:

(1) more evenly distribute sediment concentrations recorded at the gage, and

(2) allow larger sediment particles to settle out and not pass through the gage.

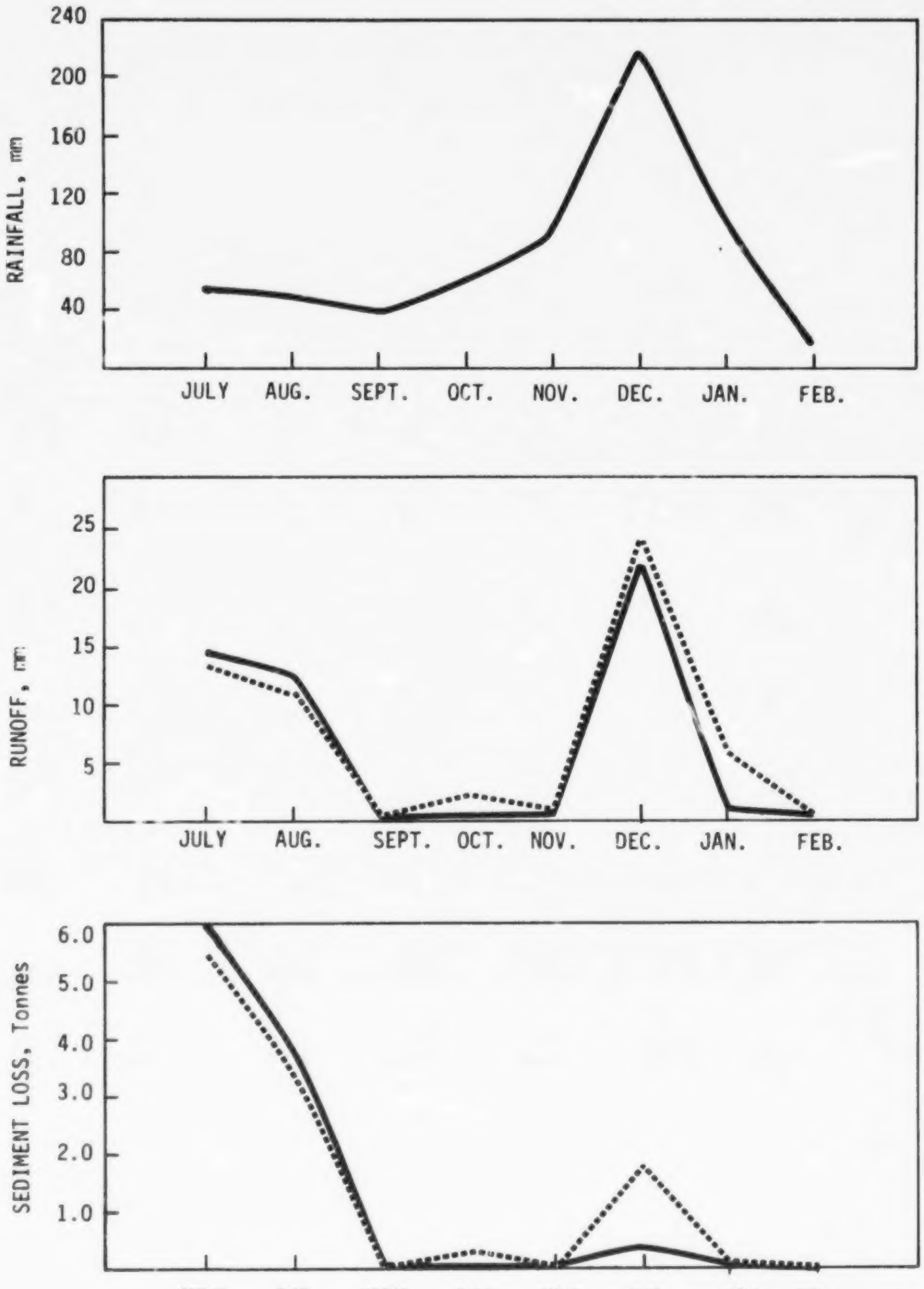


Figure 11. P1 watershed: monthly summary of rainfall, runoff, and sediment loss, (1972-73)

## Table 15. 1972 SUMMARY OF RAINFALL, RUNOFF, SEDIMENT AND PESTICIDE LOSS FROM THE P1 WATERSHED (RECORDED AND SIMULATED)

| | July | August | September | October | November | December | Total |
|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 55.6 | 54.4 | 36.8 | 59.9 | 91.4 | 216.4 | 514.5 |
| Runoff (mm) | | | | | | | |
| Recorded | 14.7 | 12.7 | 0.1 | 0.2 | 0.1 | 22.0 | 49.8 |
| Simulated | 13.3 | 10.8 | 0.4 | 1.9 | 1.0 | 23.9 | 51.3 |
| Sediment loss (tonnes) | | | | | | | |
| Recorded | 6.00 | 3.79 | 0.01 | 0.03 | 0.00 | 0.42 | 10.25 |
| Simulated | 5.47 | 3.28 | 0.05 | 0.28 | 0.07 | 1.73 | 10.88 |
| Diphenamid | | | | | | | |
| On water | | | | | | | |
| Recorded | 0.057 | 0.018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.075 |
| Simulated | 0.095 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.100 |
| On sediment | | | | | | | |
| Recorded | 0.004 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 |
| Simulated | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 |
| Total | | | | | | | |
| Recorded | 0.061 | 0.021 | 0.000 | 0.000 | 0.000 | 0.000 | 0.082 |
| Simulated | 0.099 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.104 |
| Paraquat loss (kg) | | | | | | | |
| On water | | | | | | | |
| Recorded | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.001 |
| Simulated | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| On Sediment | | | | | | | |
| Recorded | 1.211 | 0.883 | 0.001 | 0.001 | 0.000 | 0.021 | 2.117 |
| Simulated | 1.145 | 0.664 | 0.051 | 0.055 | 0.013 | 0.329 | 2.257 |
| Total | | | | | | | |
| Recorded | 1.212 | 0.883 | 0.001 | 0.001 | 0.000 | 0.021 | 2.118 |
| Simulated | 1.145 | 0.664 | 0.051 | 0.055 | 0.013 | 0.329 | 2.257 |

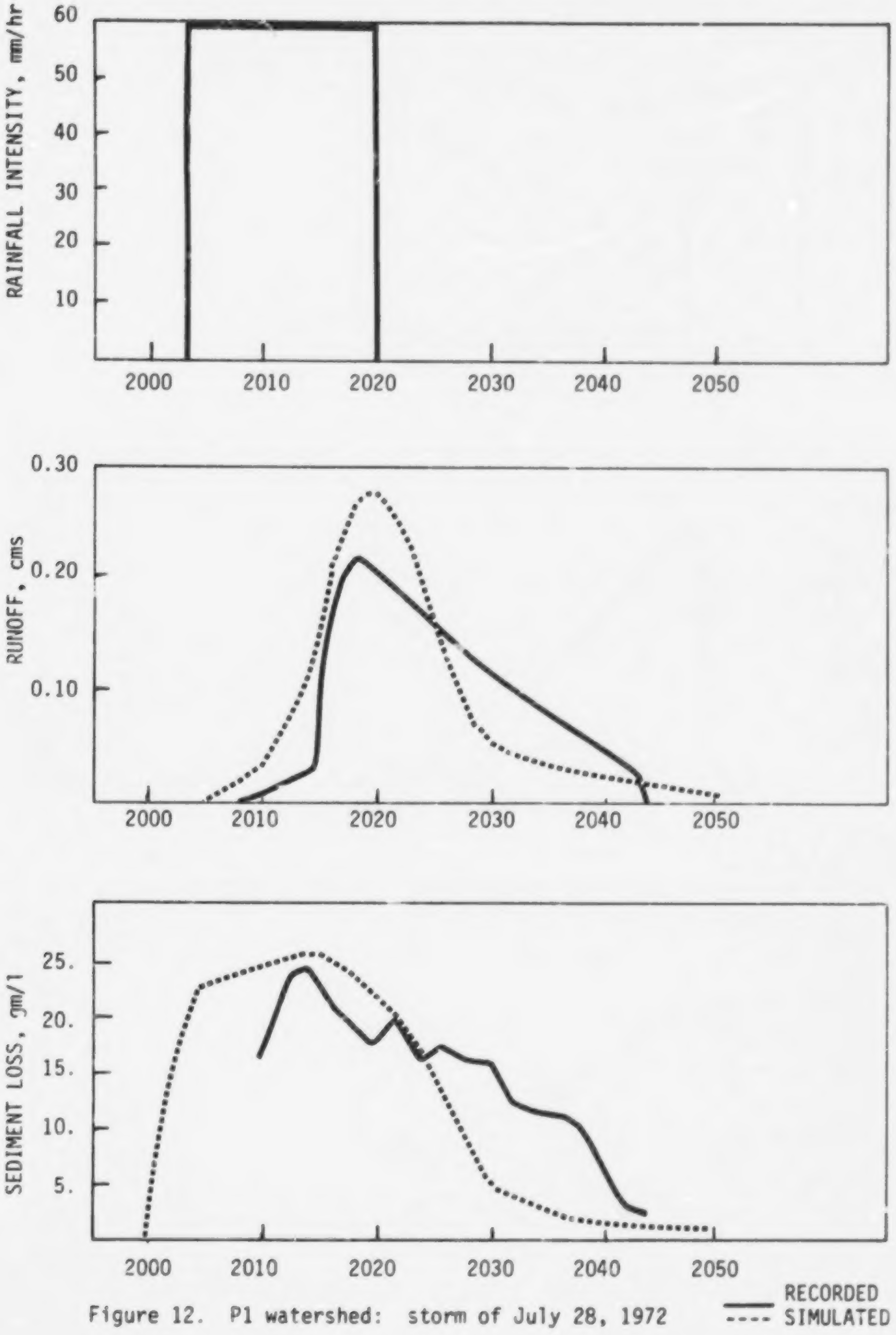


Figure 12. P1 watershed: storm of July 28, 1972

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

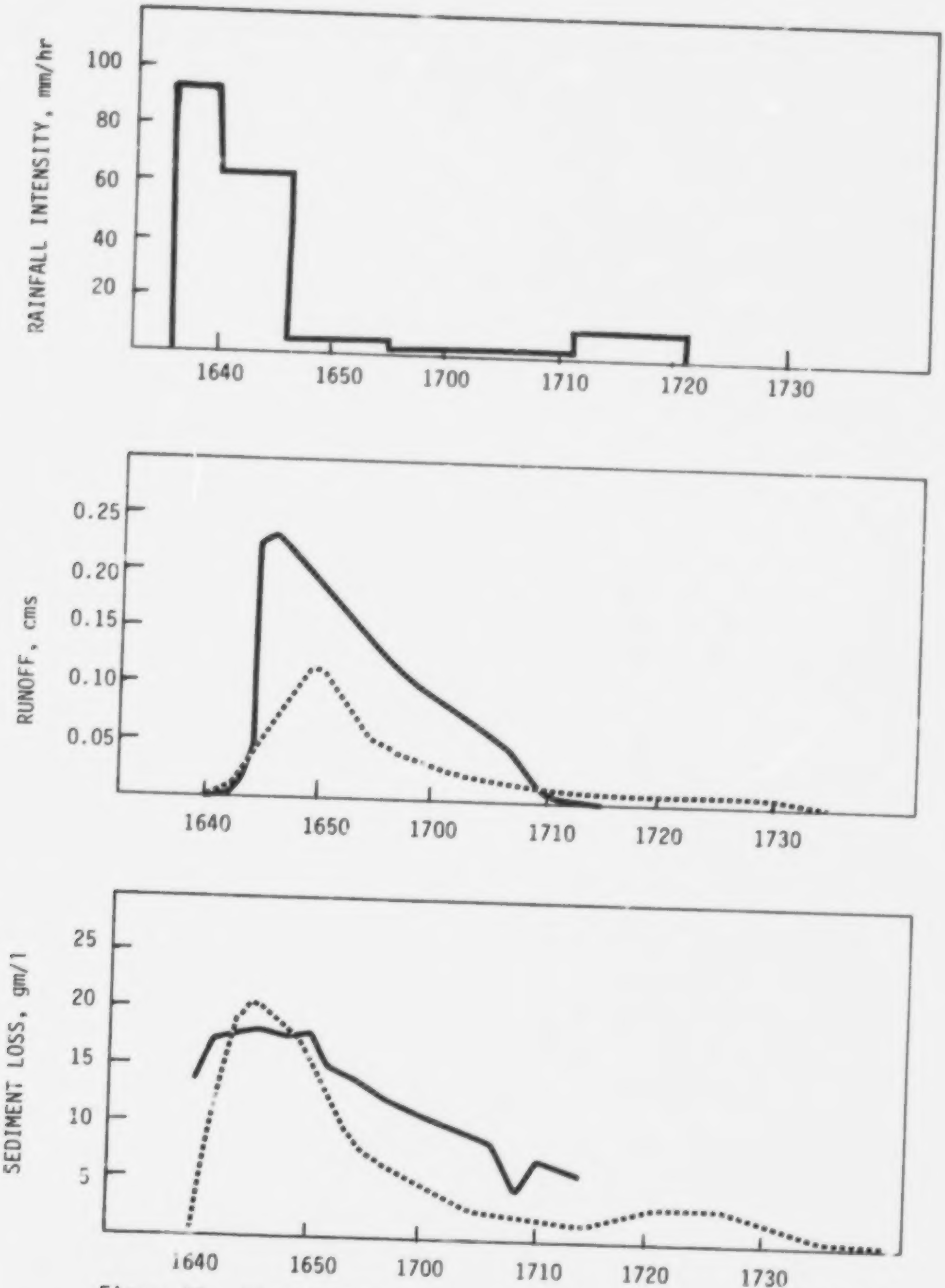


Figure 13. P1 watershed: storm of July 31, 1972

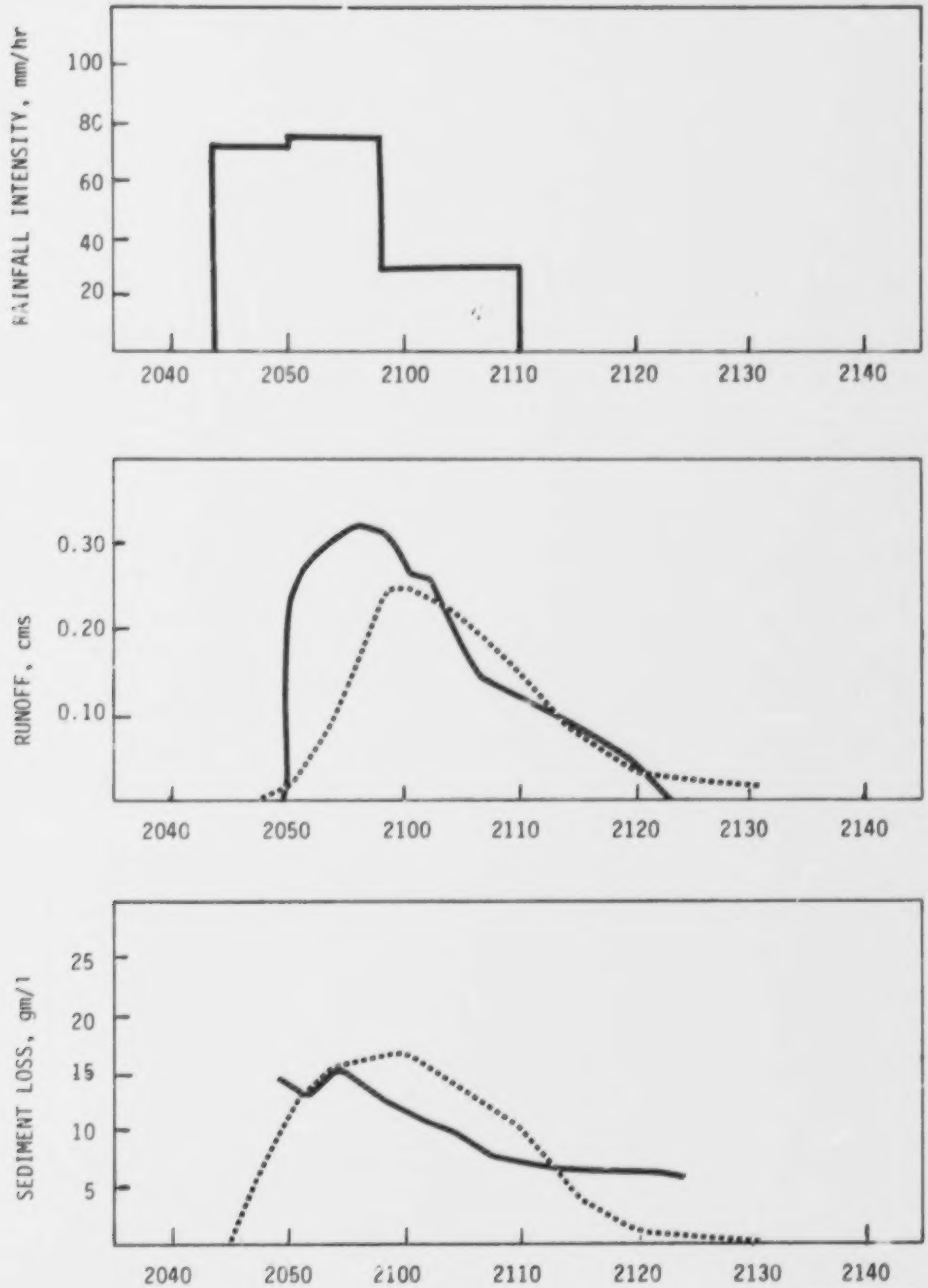


Figure 14. P1 watershed: storm of August 10, 1972

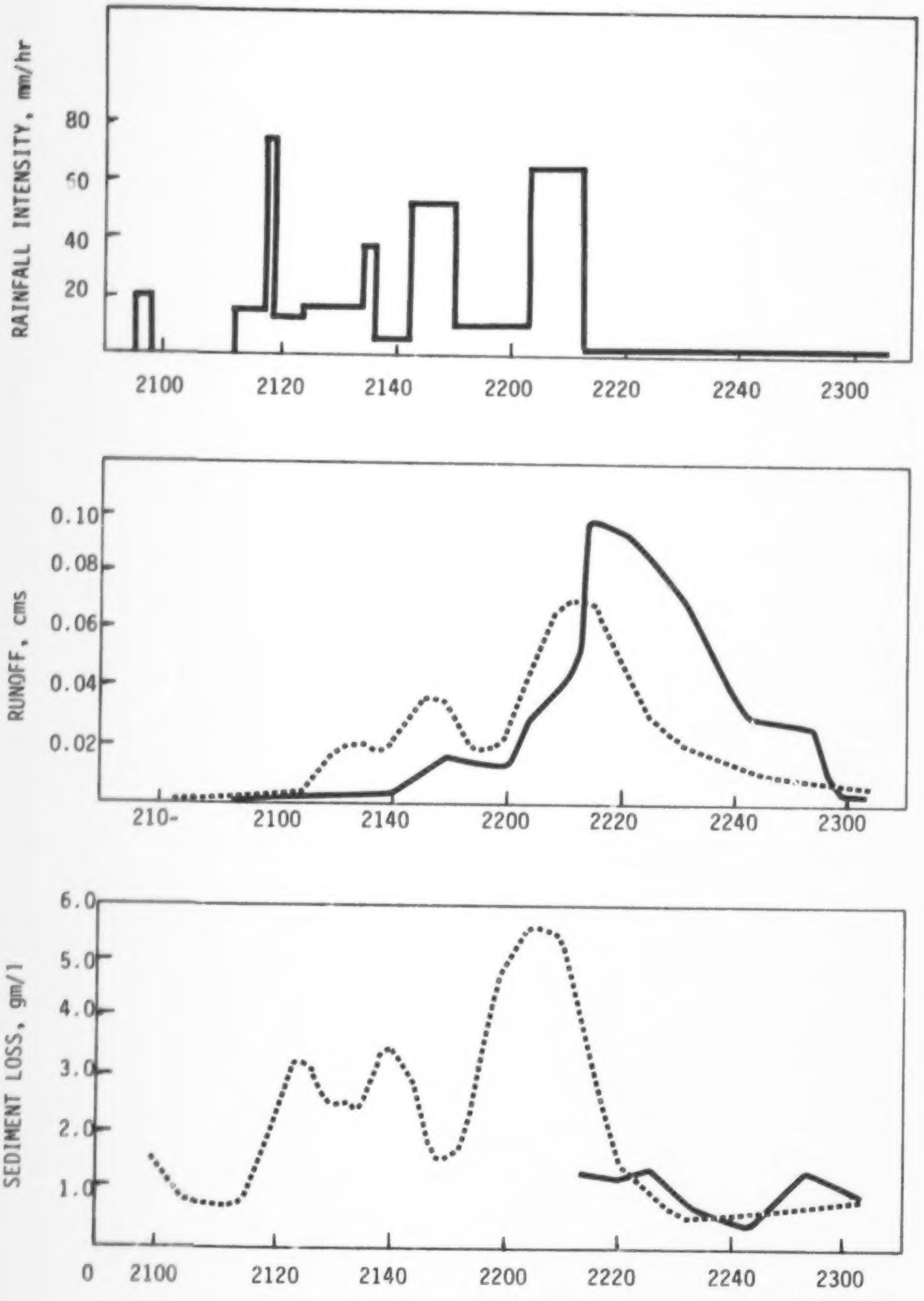


Figure 15. P1 watershed: storm of December 14, 1972 —— RECORDED
---- SIMULATED

**PESTICIDE RUNOFF** | **Hydrocomp**

The existence of the pond biased the calibrated LANDS and SEDT parameters, but the extent of the effect is impossible to determine with the existing data.

In general, the calibration appears to adequately reproduce the hydrologic response to the high-intensity summer thunderstorms, but overestimates both runoff and sediment volumes for the one long duration, low-intensity winter storm.

To test the calibration on P1, the nearby Watkinsville W1 watershed (Figure 10) was run continuously for two years (1941-42) with the P1 parameters. The P1 parameters will not apply to W1 without modification, but conclusions can be drawn about regional stability of parameters and the problem of extending parameters to ungaged streams. Simulated and recorded monthly runoff volumes are shown in Figure 16, while Figures 17 and 18 present the simulated and recorded hydrographs for the four major storms during the two year period. Although monthly volumes are underestimated during high runoff periods, storm hydrograph shape and flow peaks are accurately reproduced. Since W1 is approximately three times larger than P1, subsurface flow and groundwater components are likely to contribute more significantly to runoff on the W1 watershed. Parameter adjustments to increase these subsurface flows on W1 would increase runoff volumes (Figure 16) but would not significantly change peak flows (Figure 17 and 18). The existence of subsurface components are not reflected in the P1 calibration parameters, as is typical of very small watersheds. Also the P1 infiltration characteristics are likely to be somewhat inaccurate because calibration period was extremely dry and too short to perform a precise water balance. In summary, the W1 trial with the P1 calibration parameters accurately simulates the surface hydrologic response but is somewhat inaccurate on monthly runoff volumes because of the data and conditions for calibration. It shows encouraging evidence of the ability to transfer parameters that control the surface hydrologic response which in turn controls the transport of sediment and pesticide.

The lack of detailed sediment loss data prevented any comparison of simulated and recorded values for the W1 watershed. Estimates by the Soil Conservation Service of annual soil loss from a 135 square meter (1450 square feet) plot near the watershed amounted to 21.89 tonnes/ha /yr (9.75 tons/ac/yr)[48]. Simulated annual loss from the W1 watershed was 21.40 tonnes/ha /yr (9.53 tons/ac/yr). Consequently, simulated volumes appear to be within range of expected values. However, the validity of the simulated sediment concentrations and the monthly distribution of sediment loss on W1 is unknown. Redeposition and channel processes, which are neglected in the model, might become a significant source of error on larger watersheds.

## Pesticide Loss

Monthly values of paraquat and diphenamid collected in surface runoff (water and sediment) are presented in Figure 19. Paraquat,

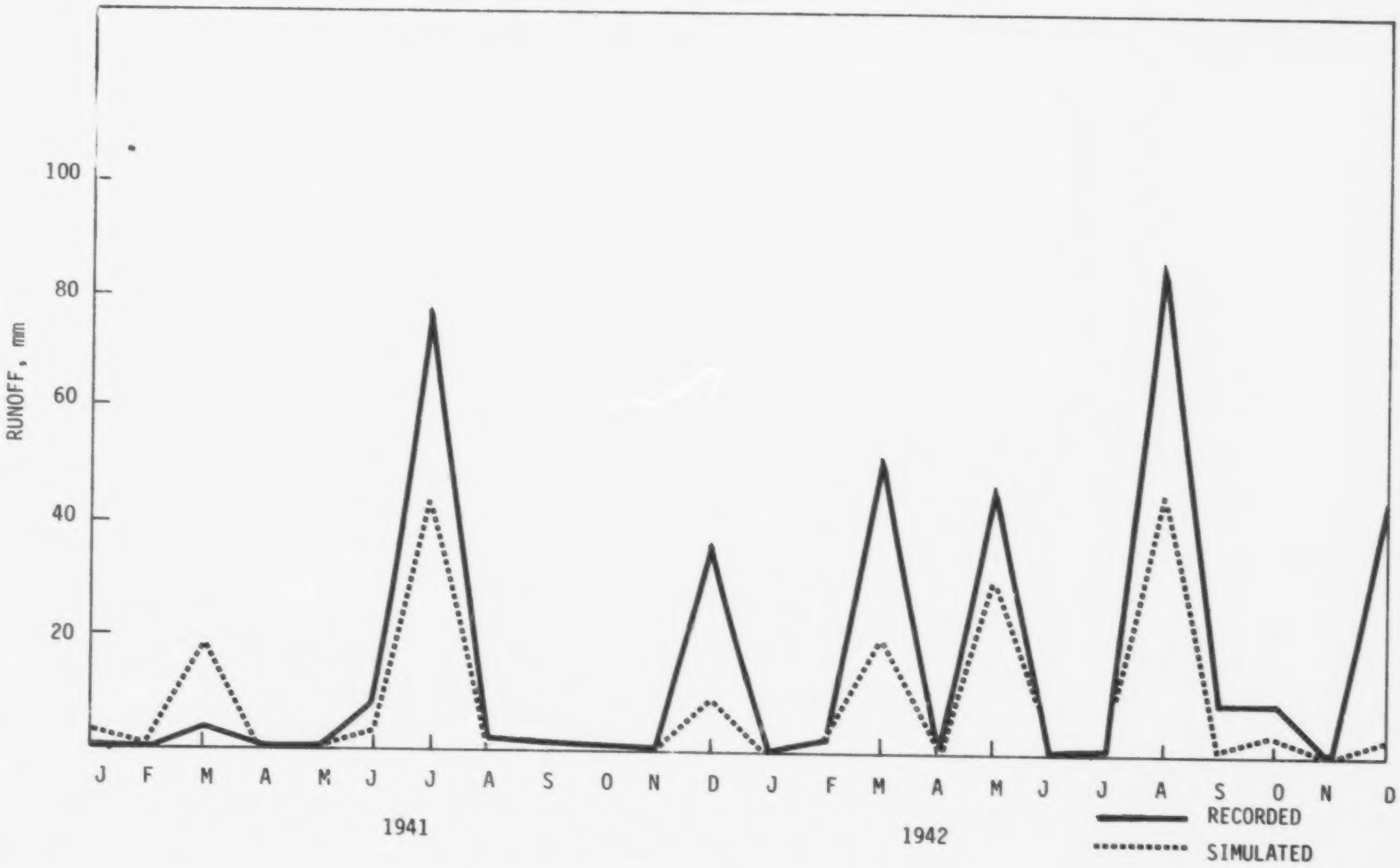


Figure 16. W1 watershed: monthly runoff volumes, (1941-42)

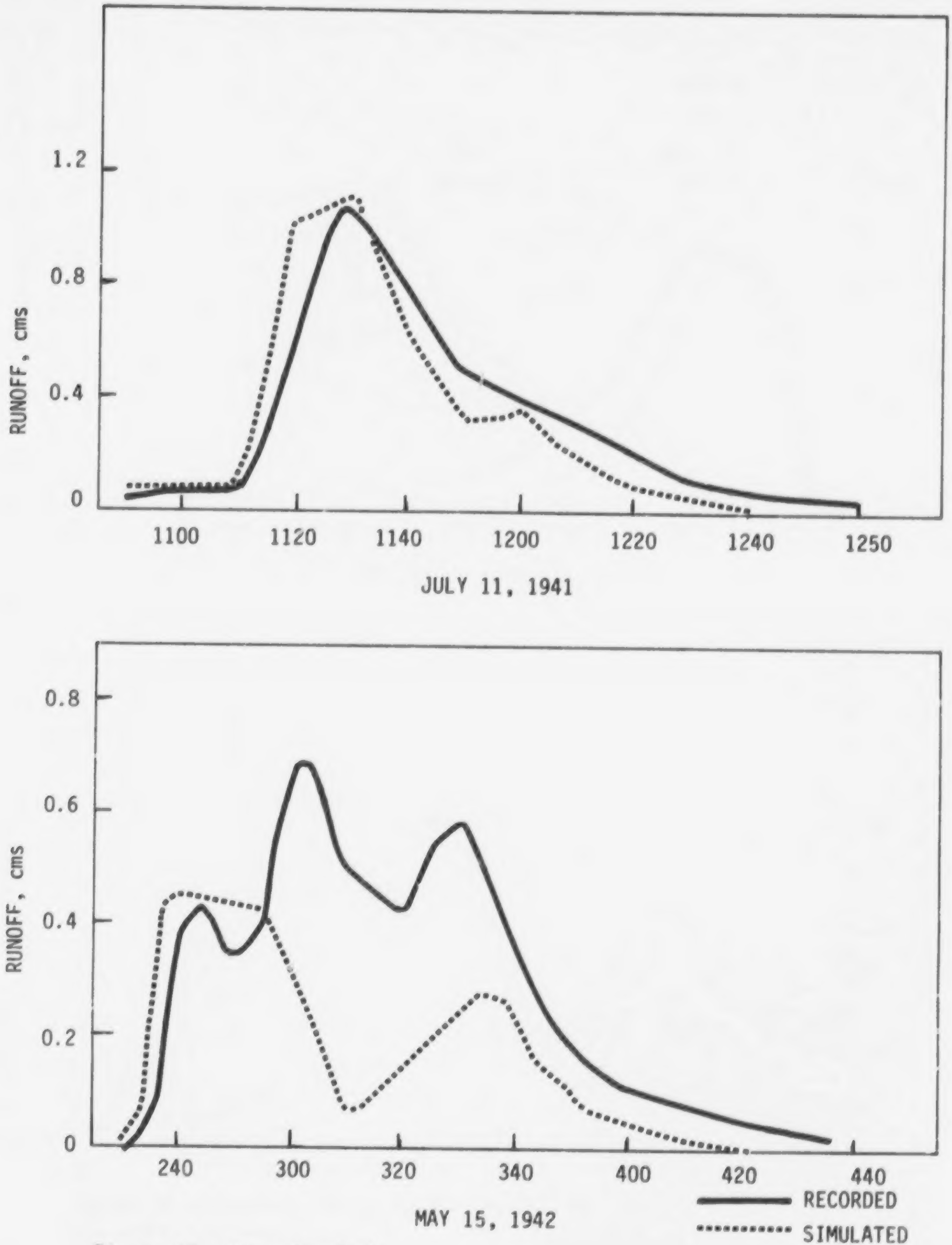


Figure 17. W1 watershed: storms of July 11, 1941 and May 15, 1942

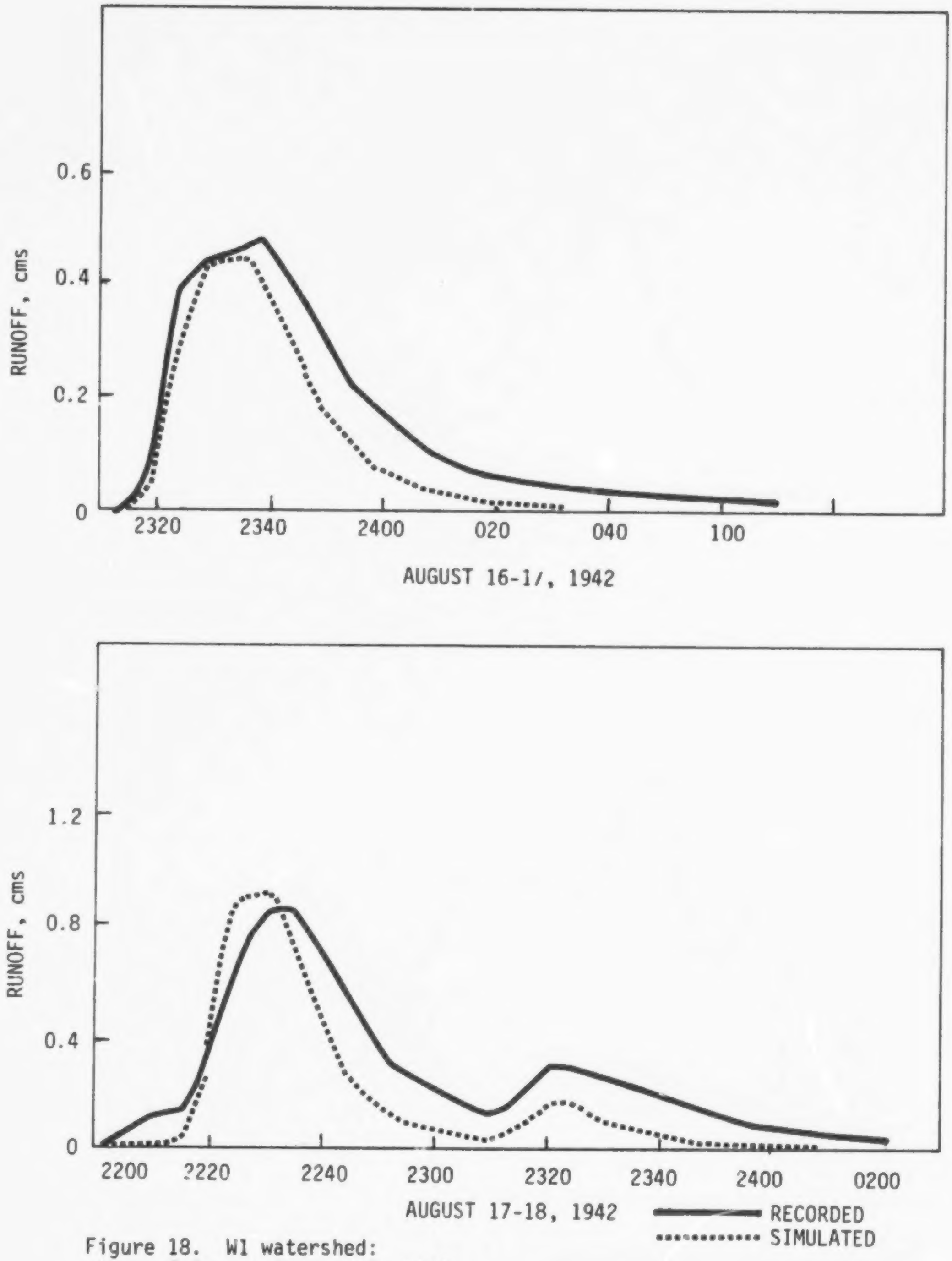


Figure 18. W1 watershed:
storm of August 16 and 17, 1942

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

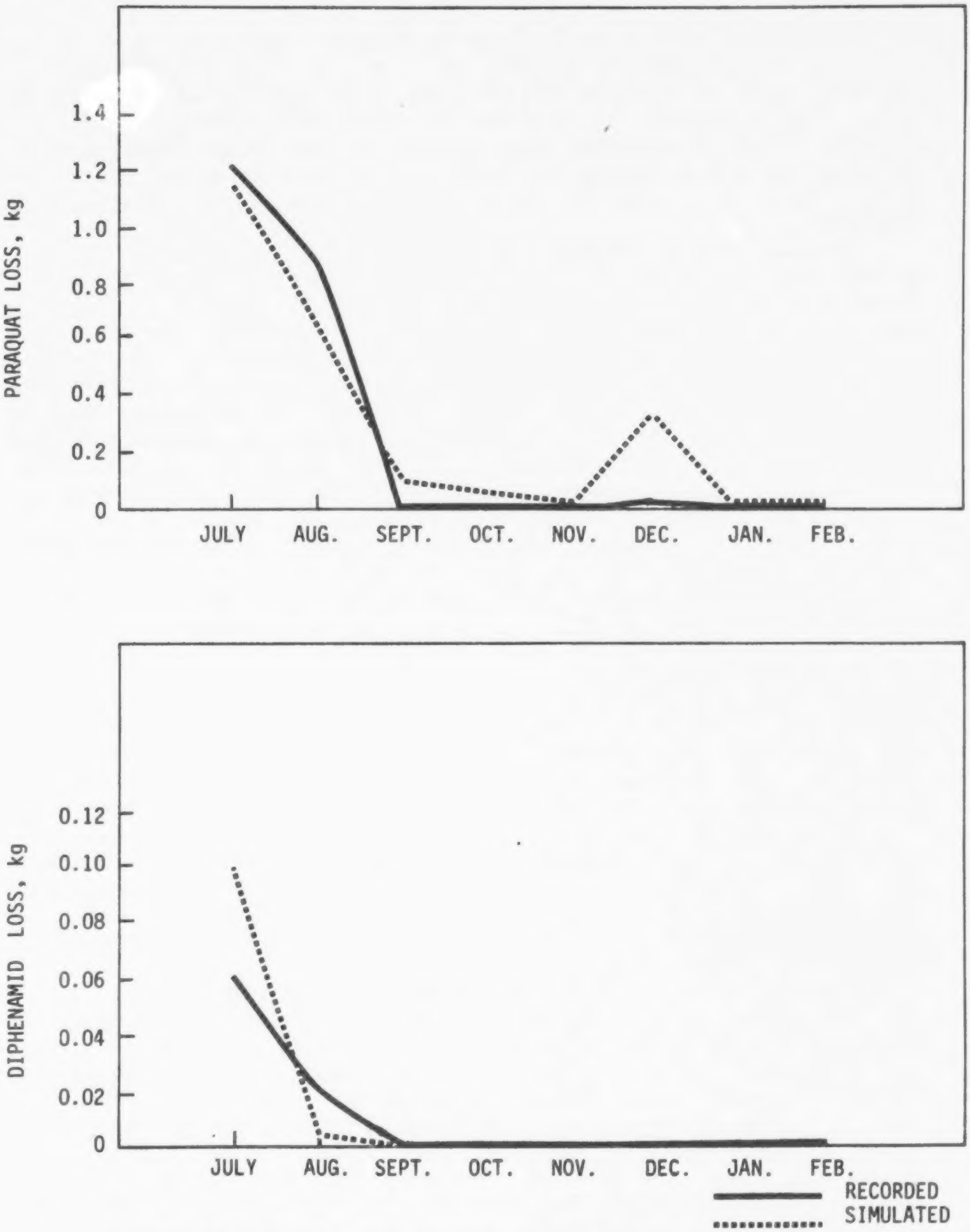


Figure 19. P1 watershed: monthly pesticide loss (1972-73)

quite predictably, closely follows the monthly sediment loss values presented previously in Figure 11. Again, the overestimate of sediment loss in December is reflected in an overestimate of paraquat loss. The variations in diphenamid loss are more difficult to explain. The first-order degradation function included in the Model may possibly underestimate diphenamid degradation during July and overestimate the rate in later periods; hence, the deviation from recorded values.

Paraquat and diphenamid concentrations on runoff and sediment during the three summer storm events are shown in Figures 20 and 21. These were the only major events for which extensive pesticide sampling was performed. The fluctuations of pesticide concentrations recorded on sediment during storm events are essentially unexplained. The pesticide concentrations do not correlate with variations in flow or sediment concentration. Also, analysis of sediment samples collected during the storm produced no obvious relationship between pesticide concentration and clay content or particle surface area. The accuracy of laboratory analytical procedures corroborates the existence of the concentration variations. Thus, the variations must result from the complex interaction of the pesticide exposed to the natural environment.

Although the concentration variations are unexplained their significance may be negligible. The loss of pesticide from the watershed is demonstrated more clearly by the mass movement of pesticide past the gage during the storm event. Figures 22 and 23 show the rate of sediment and pesticide loss on sediment (paraquat and diphenamid) for the July 28 and August 10 storms, respectively. The area under each curve represents the total volume of sediment or pesticide lost during the event. These figures demonstrate the significance of sediment loss as a mechanism of pesticide transport. This is especially true for paraquat, but is also important for diphenamid. A closer simulation of sediment loss would have improved the simulated pesticide loss. The error in simulated diphenamid loss appears to be greater than the errors in sediment or paraquat. This possibly indicates inaccuracies in the pesticide adsorption model and may warrant further investigation.

The rate of diphenamid loss on water is presented in Figure 24 for the July 28 and August 10 storms. These figures should be compared with the storm hydrographs of Figures 12 and 14. Although the simulated runoff agrees reasonably well with recorded values, substantial errors exist between recorded and simulated diphenamid loss as shown in Figure 24. The amount of pesticide lost by surface runoff is calculated in the pesticide adsorption-desorption model which determines the division between the adsorbed and dissolved phases of the pesticide. The discrepancies in Figure 24 demonstrate that further investigation and modification of the adsorption-desorption model is warranted.

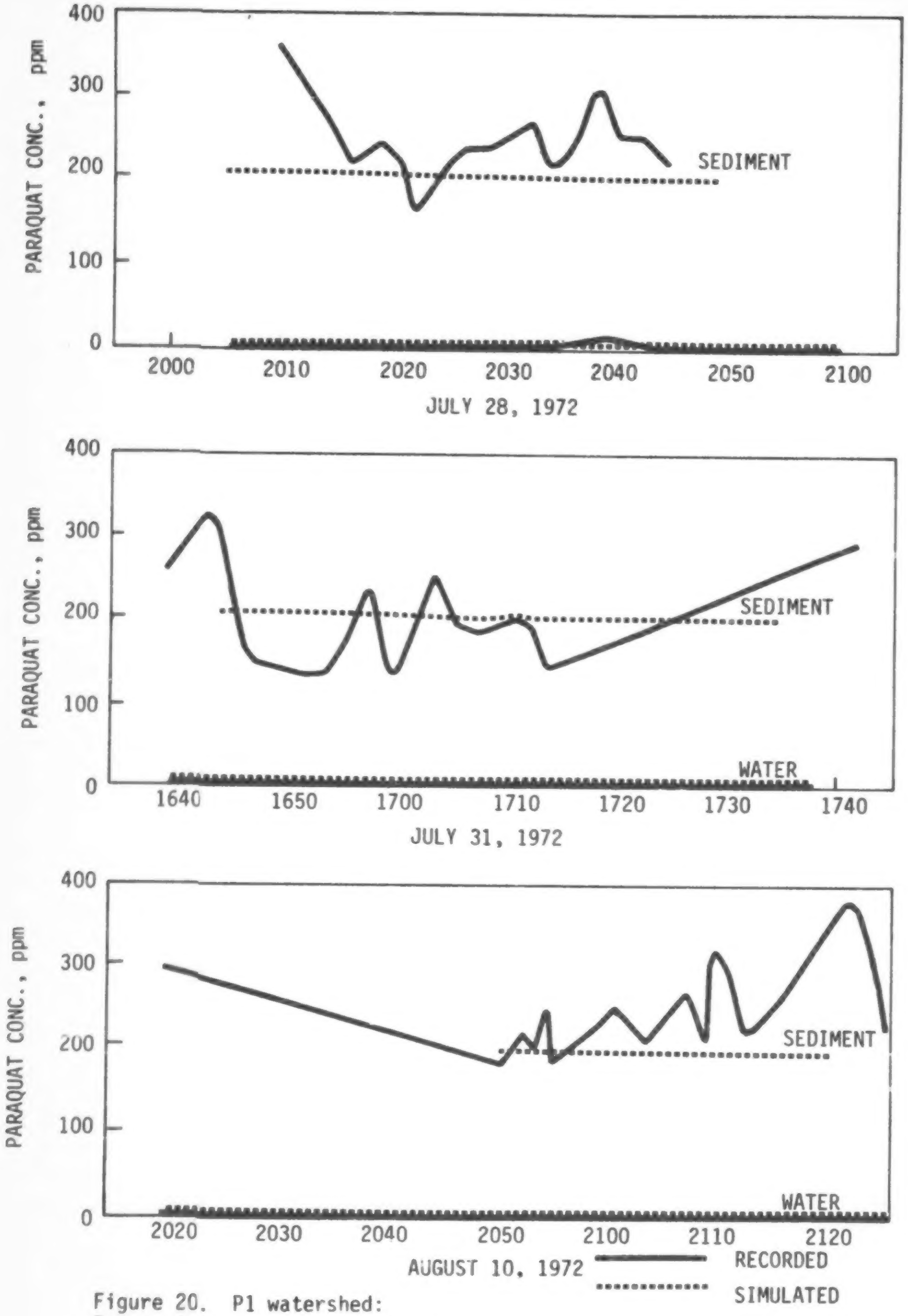


Figure 20. P1 watershed:
Paraquat in water and sediment
during storm events

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

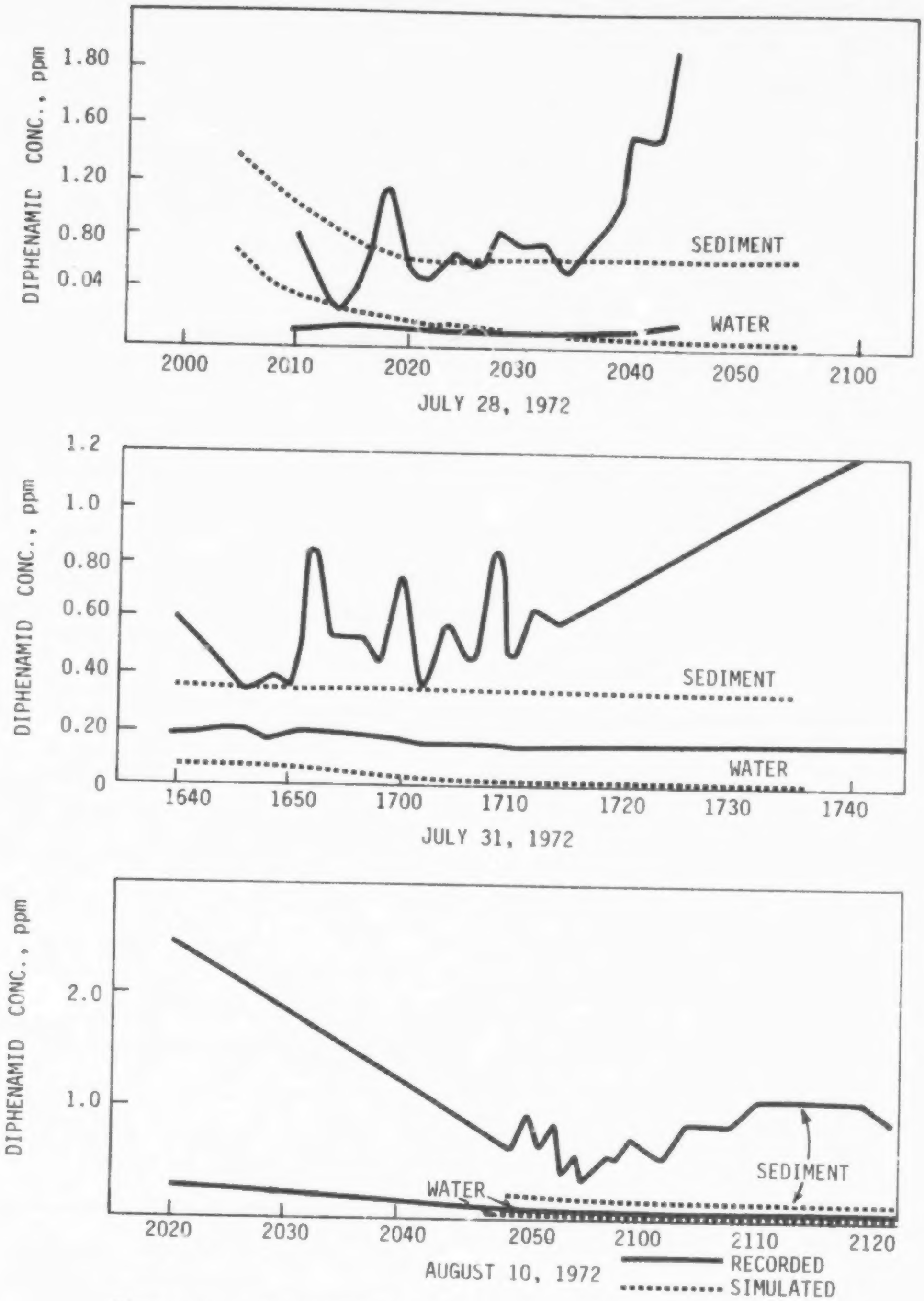


Figure 21. P1 watershed: Diphenamid in water and sediment during storm events

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

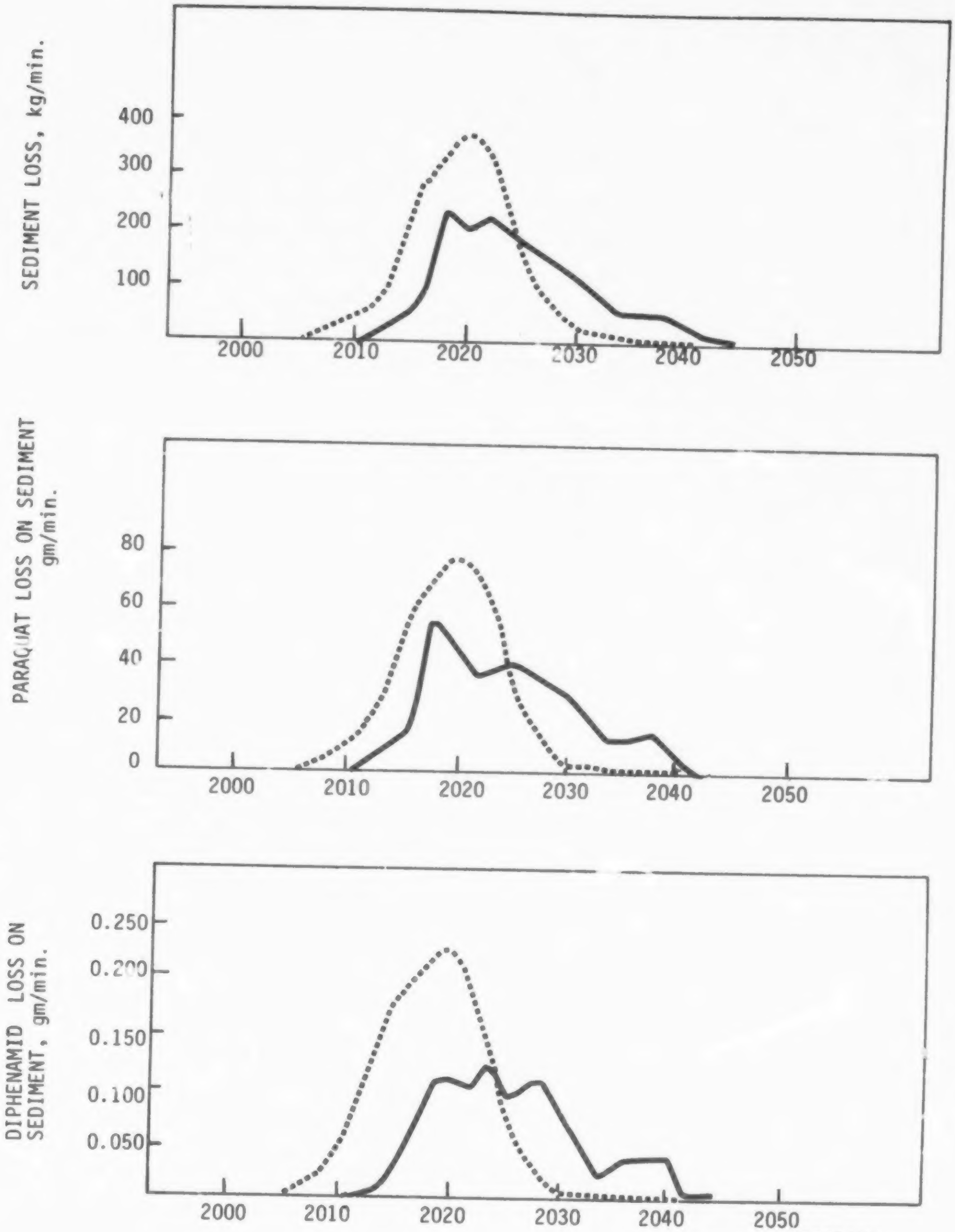


Figure 22. P1 watershed: rate of sediment and pesticide loss on sediment - July 28, 1972

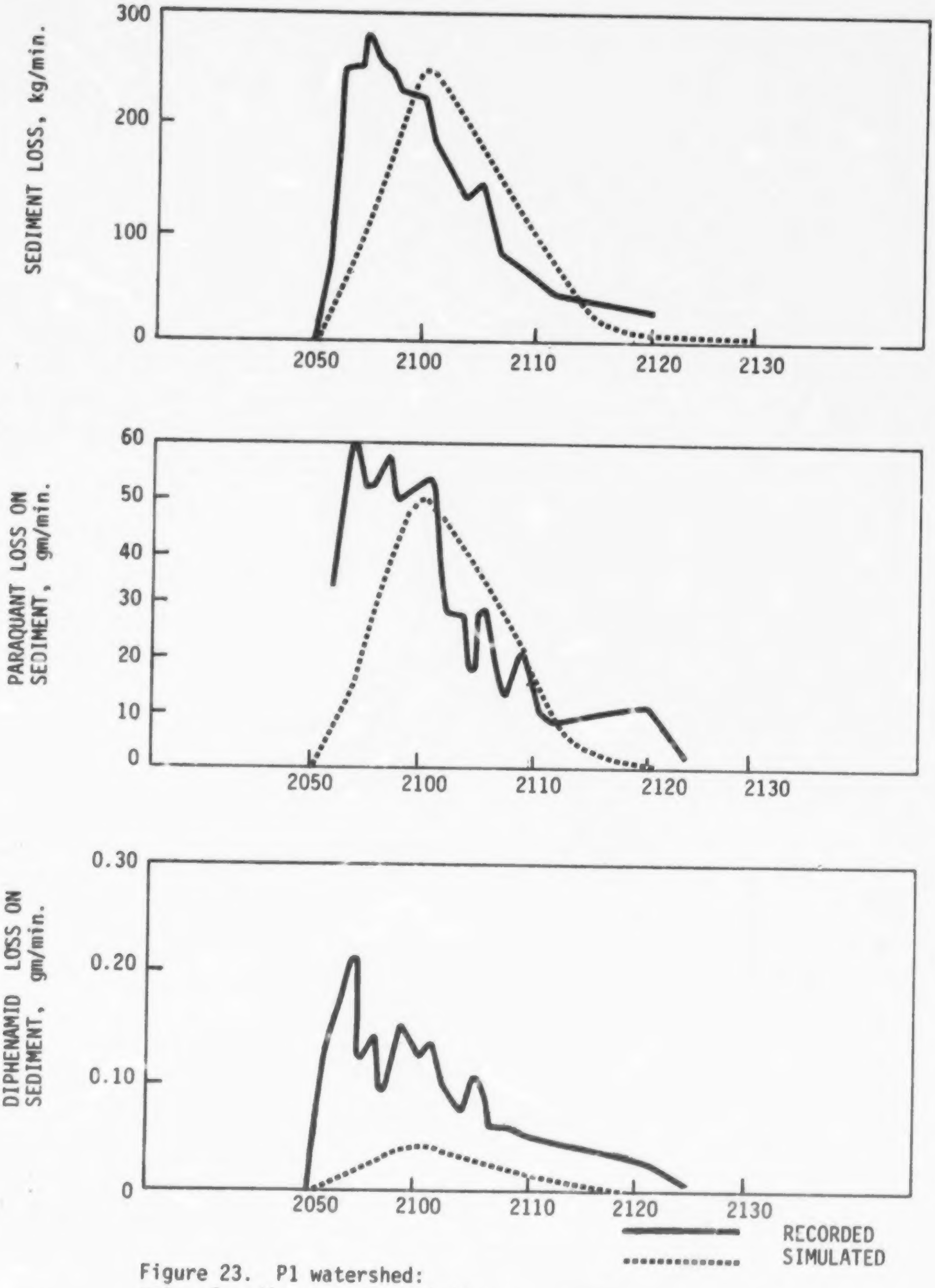


Figure 23. P1 watershed: rate of sediment and pesticide loss on sediment - August 10,1972

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

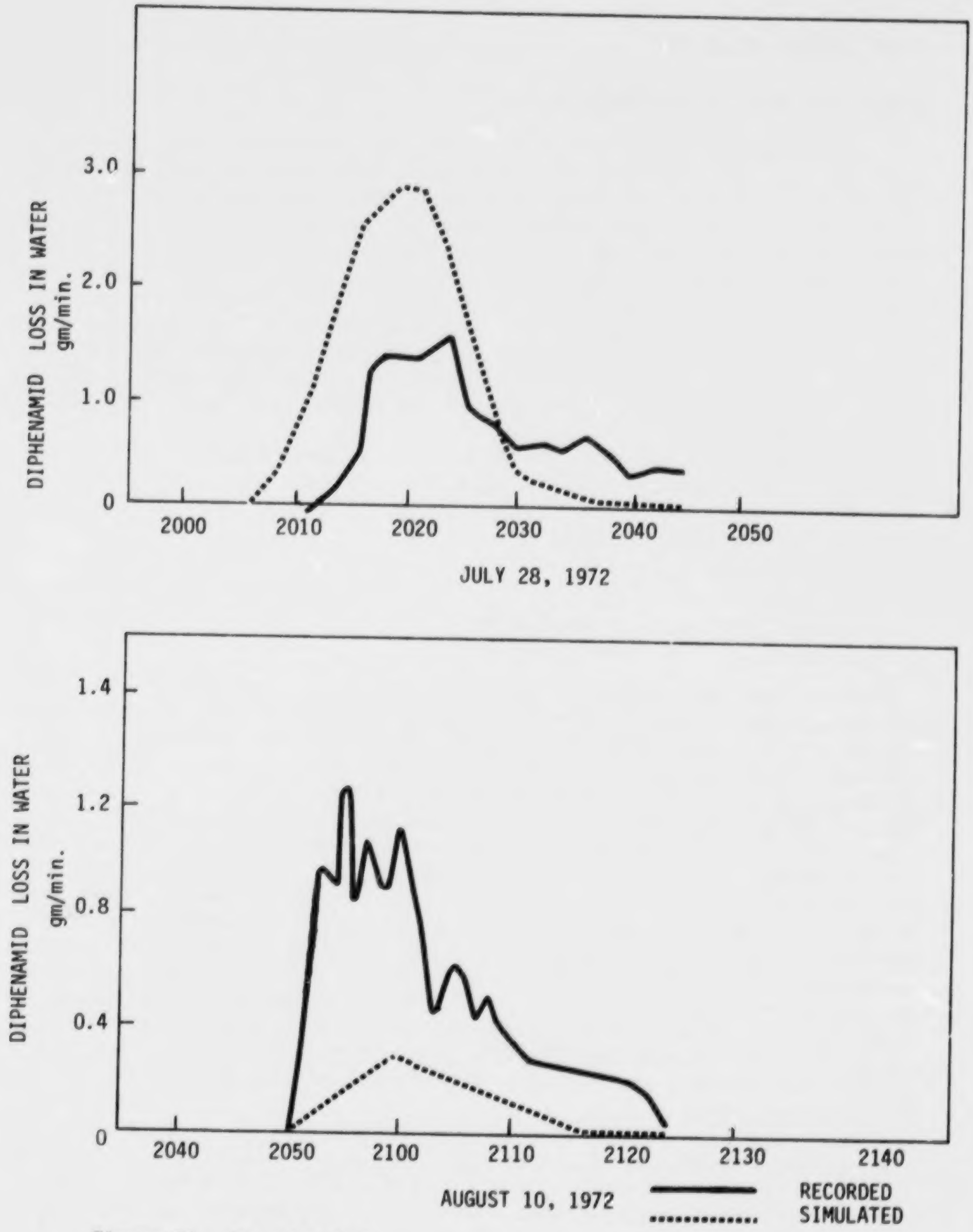


Figure 24. P1 watershed:
rate of diphenamid loss
in water, July 28 and August 10, 1972

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

## P3 WATERSHED RESULTS

### Simulation with P1 Parameters

The parameters calibrated on the P1 watershed and partially verified on the W1 watershed were used in simulation runs on the P3 watershed. Calibration was not performed separately on the P3 watershed because of data inconsistencies (explained below). The P3 watershed is terraced, has a smaller slope and a grass-lined channel, and is approximately one-half the size of the P1 watershed. Simulated and recorded monthly runoff and sediment loss is shown in Figure 25, along with recorded rainfall. The simulation period extended over five months from July to November. There is considerable discrepancy between recorded and simulated volumes of runoff and sediment loss. This discrepancy is also reflected in the monthly pesticide loss shown in Figure 26.

Monthly runoff volumes are generally underestimated, while the sediment loss values are reasonable, except for the month of September. Paraquat loss consistently followed the volumes of sediment lost, while diphenamid loss was overestimated in July as on the P1 watershed.

### Sources of Error and Data Problems

A number of possible sources of error could explain the discrepancies in the P3 simulation results. The P1 and W1 watersheds are of similar shape and both experience natural drainage. Their average land slopes are similar (0.05 for P1, and 0.07 for W1). Although P1 is one-third the area of W1, the P1 calibration parameters behaved reasonably well on the W1 watershed. The P3 watershed, on the other hand, is a terraced watershed; it has a grass-lined channel and its average slope is 0.03. Consequently, one should expect some variation in the hydrologic response of the two watersheds. Both the W1 and P3 simulation runs underestimated volumes during high runoff periods. For the W1 watershed, inaccuracies in infiltration characteristics and the lack of a groundwater component were mentioned as possible sources of error. Although groundwater is unlikely to significantly affect the P3 watershed, an overestimate of infiltration capacity could explain the discrepancies in runoff volumes. Also, the grass-lined channel could have a significant effect on runoff timing and sediment loss.

Although high runoff volumes were underestimated on both the W1 and P3 watersheds, the W1 simulated hydrographs accurately reproduced recorded values; whereas, the P3 simulated hydrographs varied considerably from the observed. From the terracing and smaller slope, one would expect less runoff to occur than simulated. However, the exact opposite occurred. Thus, the hydrologic data was investigated as another source of error. The P3 watershed is rectangular in shape and is separated from the surrounding land by a soil berm. The

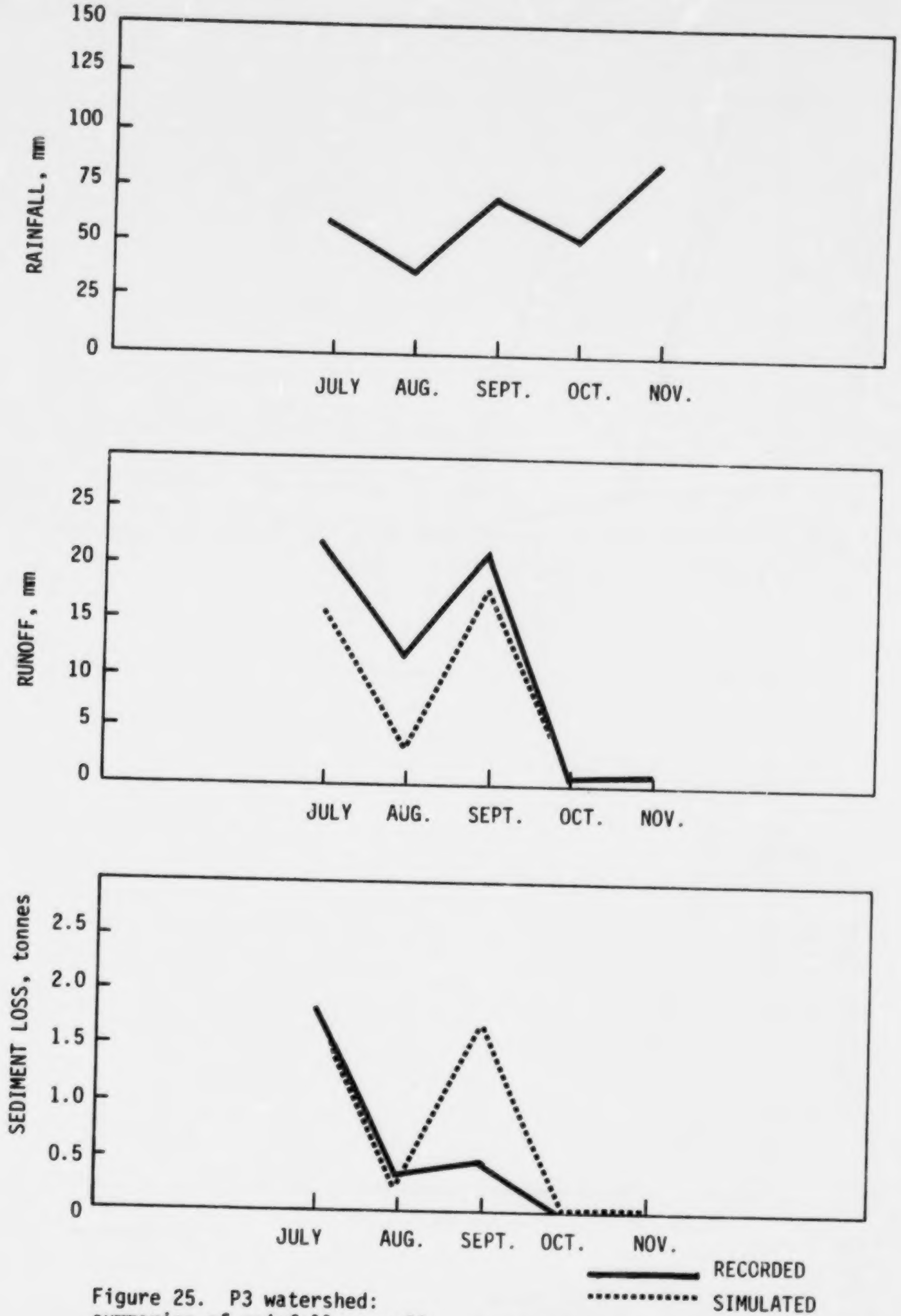


Figure 25. P3 watershed: summaries of rainfall, runoff, and sediment loss (1972)

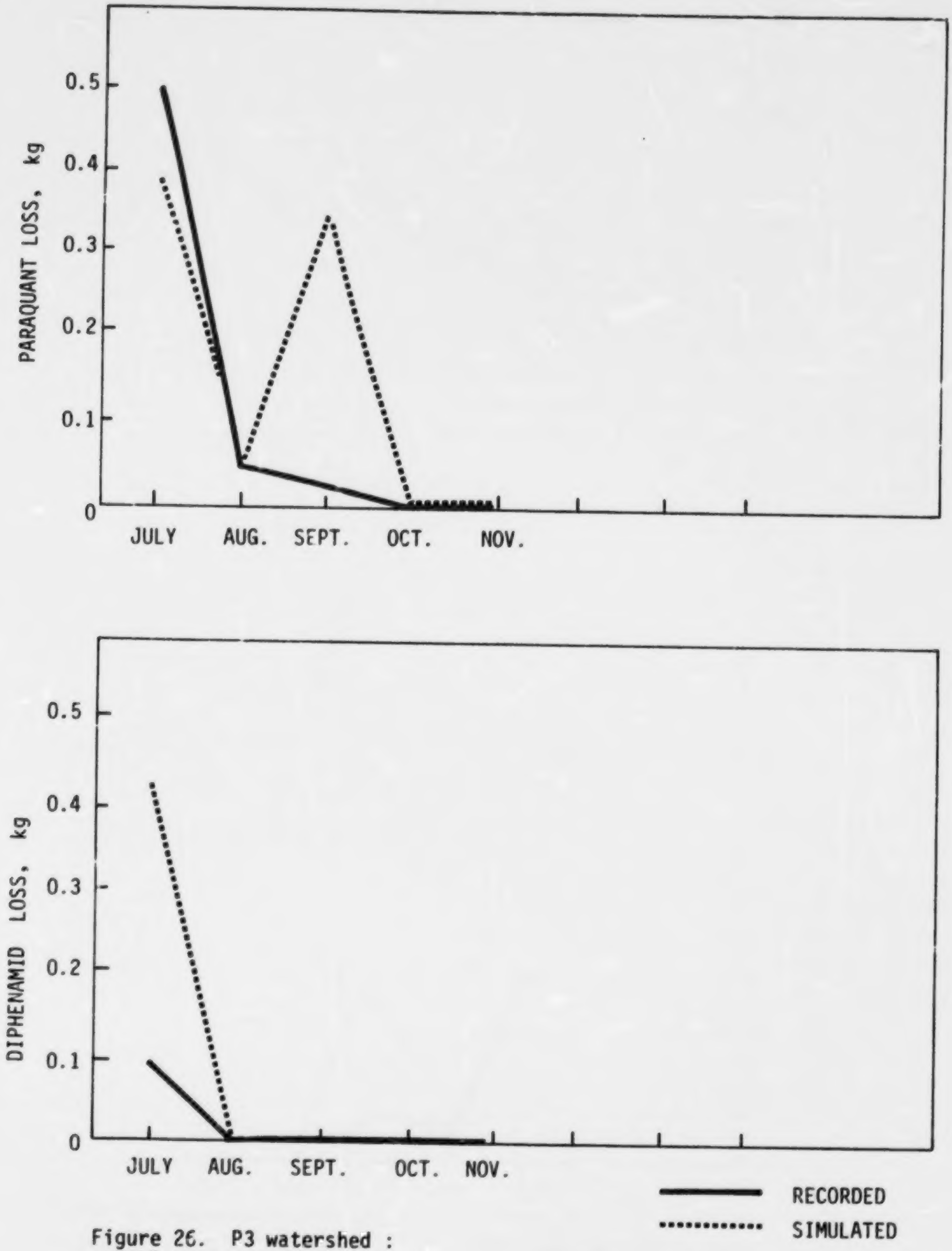


Figure 26. P3 watershed : monthly summaries of pesticide loss (1972)

probability is small that subsurface drainage conforms to this watershed boundary. Consequently, both surface and subsurface drainage that crosses the boundary would introduce substantial error in the recorded runoff data. A small 0.1 ha (0.25 ac) surface drainage plot, SP3, is located adjacent to the P3 watershed. Table 16 presents the recorded rainfall, runoff, and sediment loss for the SP3 and P3 watersheds. It can be seen that recorded depth of runoff exceeds rainfall on SP3 for three storms (7/28/72, 8/10/72, 9/4/72). This can only occur if outside drainage is entering SP3. This drainage likely originates in the P3 watershed which is located upslope. The possibility of outside drainage crossing the P3 watershed boundary is another possible source of error which could explain the discrepancies in simulated and recorded values.

In summary, the error in the simulation results on the P3 watershed is due to both surface characteristics not reflected in the calibrated parameters and inconsistences in the recorded data. Further calibration trials and additional inspections of the watershed will help to reduce these errors and improve simulation results.

## DISCUSSION OF SIMULATION RESULTS

In spite of inconclusive results from the P3 watershed simulation, the Model results from the P1 and W1 watersheds simulations provide ample evidence of the capabilities and inadequacies of the PTR Model. It is evident that a reliable hydrologic and sediment transport simulation is paramount to simulating pesticide loss from agricultural lands. The calibration of the P1 watershed and the verification of the parameters on the W1 watershed demonstrates that the LANDS subprogram can reliably simulate surface runoff from agricultural watersheds. Moreover, the calibrated parameters are applicable to the geographic region rather than to specific individual watersheds. Based on surface runoff and input rainfall, the SEDT subprogram estimates of monthly sediment loss are reasonably close to recorded values. However, simulated hydrographs and sediment concentrations appear to recede more rapidly than recorded during the storm events. The weir pond formed in front of the P1 gage may be partially responsible.
Also, lack of experience with sediment loss calibration and/or inaccuracies in the basic algorithms could be partially at fault.

The pesticide functions of adsorption-desorption, volatilization, and degradation performed reasonably well for Paraquat but were in error when simulating diphenamid loss. The reasons for this are as follows:

(1) Volatilization and degradation are major attenuation mechanisms for diphenamid but are not significant for paraquat. The volatilization functions were not operated during simulation runs because of the lack of necessary parameters and verification data. Degradation was assumed to be first order.

## Table 16. RAINFALL, RUNOFF, AND SEDIMENT LOSS FOR SP3 AND P3 WATERSHEDS

| Storm date | Rainfall (mm) | SP3 Watershed (0.10 ha) Runoff (mm) | SP3 Watershed (0.10 ha) Sediment loss (kg/ha) | P3 Watershed (1.25 ha) Runoff (mm) | P3 Watershed (1.25 ha) Sediment loss (kg/ha) |
|---|---|---|---|---|---|
| 7/02/72 | 19.05 | 6.43 | 1121 | 3.40 | 454 |
| 7/02/72 | 6.10 | 0.51 | 113 | 0.02 | 2 |
| 7/28/72 | 21.84 | 38.35 | 5426 | 10.67 | 611 |
| 7/31/72 | 11.43 | 7.87 | 794 | 6.60 | 395 |
| 8/09/72 | 8.13 | 2.08 | 191 | 1.14 | 25 |
| 8/10/72 | 10.92 | 13.56 | 1157 | 5.33 | 140 |
| 8/23/72 | 17.27 | 11.30 | 327 | 5.33 | 134 |
| 9/04/72 | 49.28 | 75.18 | 1856 | 21.08 | 350 |
| 9/30/72 | 12.70 | 0.64 | - | 0.01 | - |
| 10/27/72 | 35.56 | 16.69 | - | 0.52 | - |

(2) For degradable pesticides, rates of degradation are high during the first days and/or weeks following application. In later periods, the rate usually decreases to essentially constant baseline values. The first-order rate used in the Model was determined by calculating the daily rate which would allow remaining pesticide levels to be approximately those determined by the soil core samples of October 30, 1972. This first-order rate likely underestimates losses immediately after application, and overestimates losses in later periods. This would introduce error into the monthly pesticide losses.

(3) The attraction of paraquat to soil particles is such that the entire paraquat application is adsorbed in the surface layer. In soils with a high capacity for adsorption, the Model assumes that all the paraquat is adsorbed and consequently bypasses the Freundlich adsorption curve.

(4) Since diphenamid is not permanently fixed to soil particles, the distribution between adsorbed and dissolved phases is determined by the Freundlich adsorption curve. Errors in the adsorption/desorption parameters and/or the basic adsorption/desorption algorithm would thus have a greater effect on diphenamid loss than on paraquat. The effect of the adsorption model on diphenamid loss is shown most dramatically in Figures 22, 23, and 24. Although recorded and simulated flow and sediment loss are in substantial agreement, simulated diphenamid loss deviates from the observed.

The source-zone approach, described in Section V, produced an areal variation in runoff, sediment and pesticide loss. Tables 17 and 18 summarize simulation results for 1972 for paraquat and diphenamid, respectively. The Model predicts that 50% or more of total runoff, sediment, and diphenamide loss is derived from 20% of the total watershed area. Paraquat loss is more widespread; 50 percent originating from approximately 30 percent of the watershed area. The variable loss of pesticide from the source-zones also produced an areal variation in pesticide remaining as shown in Tables 17 and 18. The sampling on October 30 determined that the remaining amounts of paraquat and diphenamid were 29.96 kg(65.91 lb) and 2.33 kg (5.13 lb); corresponding simulated values were 28.23 kg (62.11 lb) and 2.39 kg (5.26 lb). This close agreement is a result of the calculated degradation constant. The main emphasis is that although total volumes agree, the recorded and simulated concentrations across the watershed deviate considerably. Since concentration is highly dependent on the mass of soil available, the depths of the soil zones in the Model would have a major effect on simulated concentrations. Additional work with a variety of soil zone depths would help to determine the importance of this factor.

## Table 17. 1972 SUMMARY: PARAQUAT SIMULATION ON P1 WATERSHED

```
                         SUMMARY_FOR_1972

                         ZONE 1    ZONE 2    ZONE 3    ZONE 4    ZONE 5     TOTAL
 WATER, INCHES

    PRECIPITATION        20.260    20.260    20.260    20.260    20.260    20.260

    RUNOFF
       OVERLAND_FLOW      4.275     1.417     0.683     0.360     0.161     1.379
       INTERFLOW          1.202     0.804     0.576     0.372     0.259     0.643
       IMPERVIOUS                                                           0.0
       TOTAL              5.478     2.221     1.259     0.732     0.420     2.022

    BASE_FLOW                                                               0.0
    GROWATER_RECHARGE                                                       5.241

    EVAPORATION
       POTENTIAL         19.717    19.717    19.717    19.717    19.717    19.717
       NET               14.588    14.588    14.588    14.588    14.588    14.588

    STORAGES
       UPPER_ZONE         0.085     0.017     0.0       0.0       0.0       0.022
       LOWER_ZONE        18.417    18.417    18.417    18.417    18.417    18.417
       GROUNDWATER        0.0       0.0       0.0       0.0       0.0       0.0
       INTERCEPTION       0.0       0.0       0.0       0.0       0.0       0.0
       OVERLAND_FLOW      0.0       0.0       0.0       0.0       0.0       0.0
       INTERFLOW          0.0       0.0       0.0       0.0       0.0       0.0

    WATER_BALANCE=  0.0011

   SEDIMENT, TONS
    TOTAL SEDIMENT LOSS   4.069     3.374     2.325     1.456     0.748    11.971
    FINES DEPOSIT         0.063     0.759     1.807     2.677     3.385     8.691
    IMPERVIOUS EROSION                                                      0.0

PESTICIDE, POUNDS

   SURFACE LAYER         11.541    11.803    12.210    12.560    12.852    60.966
      ADSORBED           11.542    11.804    12.212    12.561    12.854    60.972
      CRYSTALLINE         0.0       0.0       0.0       0.0       0.0       0.0
      DISSOLVED           0.0       0.0       0.0       0.0       0.0       0.0

   UPPER ZONE LAYER       0.0       0.0       0.0       0.0       0.0       0.0
      ADSORBED            0.0       0.0       0.0       0.0       0.0       0.0
      CRYSTALLINE         0.0       0.0       0.0       0.0       0.0       0.0
      DISSOLVED           0.0       0.0       0.0       0.0       0.0       0.0

   LOWER ZONE LAYER                                                         0.0
      ADSORBED                                                              0.0
      CRYSTALLINE                                                           0.0
      DISSOLVED                                                             0.0

   GROUNDWATER LAYER                                                        0.0
      ADSORBED                                                              0.0
      CRYSTALLINE                                                           0.0
      DISSOLVED                                                             0.0

   PESTICIDE REMOVAL, LBS.   1.627   .365     0.958     0.609     0.316     4.875
      OVERLAND FLOW REMOVAL  0.0     0.0      0.0       0.0       0.0       0.0
      SEDIMENT REMOVAL       1.627   1.365    0.958     0.609     0.316     4.875
      INTERFLOW REMOVAL      0.0     0.0      0.0       0.0       0.0       0.0

   PESTICIDE VOLATILIZATION LOSS, LBS.
      TOTAL                                                                 0.0
      FROM SURFACE                                                          0.0
      FROM UPPER ZONE                                                       0.0

   PESTICIDE DEGRADATION LOSS, LBS.
      TOTAL                                                                 1.159
      FROM SURFACE                                                          1.159
      FROM UPPER ZONE                                                       0.0
      FROM LOWER ZONE                                                       0.0

      PESTICIDE_BALANCE=  0.0
```

## Table 18. 1972 SUMMARY: DIPHENAMID SIMULATION ON P1 WATERSHED

```
              SUMMARY FOR 1972

                               ZONE 1    ZONE 2    ZONE 3    ZONE 4    ZONE 5    TOTAL
    WATER, INCHES

       PRECIPITATION           20.260    20.260    20.260    20.260    20.260    20.260

       RUNOFF
          OVERLAND_FLOW         4.275     1.417     0.683     0.360     0.161     1.379
          INTERFLOW             1.202     0.804     0.576     0.372     0.259     0.643
          IMPERVIOUS                                                              0.0
          TOTAL                 5.478     2.221     1.259     0.732     0.420     2.022

       BASE_FLOW                                                                  0.0
       GRDWATER_RECHARGE                                                          5.241

       EVAPORATION
          POTENTIAL            19.717    19.717    19.717    19.717    19.717    19.717
          NET                  14.588    14.588    14.588    14.588    14.588    14.588

       STORAGES
          UPPER_ZONE            0.085     0.017     0.0       0.0       0.0       0.022
          LOWER_ZONE           18.417    18.417    18.417    18.417    18.417    18.417
          GROUNDWATER           0.0       0.0       0.0       0.0       0.0       0.0
          INTERCEPTION          0.0       0.0       0.0       0.0       0.0       0.0
          OVERLAND_FLOW         0.0       0.0       0.0       0.0       0.0       0.0
          INTERFLOW             0.0       0.0       0.0       0.0       0.0       0.0

       WATER_BALANCE=  0.0011

    SEDIMENT, TONS
       TOTAL SEDIMENT LOSS      4.069     3.374     2.325     1.456     0.748    11.971
       FINES DEPOSIT            0.063     0.759     1.807     2.677     3.385     8.691
       IMPERVIOUS EROSION                                                         0.0
 PESTICIDE, POUNDS

    SURFACE LAYER               0.000     0.000     0.000     0.000     0.000     0.001
       ADSORBED                 0.000     0.000     0.000     0.000     0.000     0.001
       CRYSTALLINE              0.0       0.0       0.0       0.0       0.0       0.0
       DISSOLVED                0.0       0.0       0.0       0.0       0.0       0.0

    UPPER ZONE LAYER            0.419     0.528     0.555     0.563     0.568     2.633
       ADSORBED                 0.425     0.533     0.560     0.569     0.574     2.662
       CRYSTALLINE              0.0       0.0       0.0       0.0       0.0       0.0
       DISSOLVED                0.000     0.000     0.0       0.0       0.0       0.001

    LOWER ZONE LAYER
       ADSORBED                                                                   0.000
       CRYSTALLINE                                                                0.0
       DISSOLVED                                                                  0.0
                                                                                  0.0
    GROUNDWATER LAYER
       ADSORBED                                                                   0.0
       CRYSTALLINE                                                                0.0
       DISSOLVED                                                                  0.0
                                                                                  0.0
    PESTICIDE REMOVAL, LBS.     0.153     0.045     0.018     0.010     0.005
       OVERLAND FLOW REMOVAL    0.148     0.042     0.017     0.009     0.004     0.231
       SEDIMENT REMOVAL         0.005     0.003     0.002     0.001     0.001     0.220
       INTERFLOW REMOVAL        0.0       0.0       0.0       0.0       0.0       0.011
                                                                                  0.0
    PESTICIDE VOLATILIZATION LOSS, LBS.
       TOTAL
       FROM SURFACE                                                               0.0
       FROM UPPER ZONE                                                            0.0
                                                                                  0.0
    PESTICIDE DEGRADATION LOSS, LBS.
       TOTAL
       FROM SURFACE                                                              17.223
       FROM UPPER ZONE                                                            0.778
       FROM LOWER ZONE                                                           16.445
                                                                                  0.000
       PESTICIDE_BALANCE= -0.0484
```

Table 19 presents an approximate mass-balance of the pesticides applied to the P1 watershed. Less than 1 percent of the applied diphenamid was lost by runoff and sediment loss; almost 7 percent of the paraquat was lost by these mechanisms. Since paraquat is essentially non-degradable, the discrepancy in the mass-balance is likely due to errors in the application equipment and/or problems in obtaining representative samples across the watershed. For diphenamid the mass balance error in Table 19 is due to various mechanisms of degradation. Table 19 demonstrates the relative importance of the various loss mechanisms for each of the pesticides.

The simulated vertical movement of the pesticides can be determined from Tables 17 and 18. Paraquat remained completely in the surface zone, whereas diphenamid was moved to the upper zone by percolating water. The observed vertical movement of the pesticides was much greater than simulated. Paraquat was recorded at depths down to 10 cm (4 inches) or more, while diphenamid was much more evenly distributed and observed at even lower depths. This is further evidence that the adsorption-desorption routine requires additional investigation.

In summary, the basic conclusions that can be observed from the PTR Model results are as follows:

1. The PTR Model was developed to simulate the transport of pesticides in solution and on sediment. The Model uses physically - based submodels to calculate runoff volumes and sediment concentrations. Initial model tests show good results for transport of pesticides on sediment and fair-to-good results for transport in solution.

2. Surface runoff from agricultural lands in the Southern Piedmont can be simulated with reasonable accuracy with the PTR Model. The hydrologic submodel has been used extensively in other studies, and past experience indicates that similar simulation accuracy for runoff volumes can be expected in other geographical regions.

3. Simulation of monthly sediment loss agrees adequately with recorded volumes; however, sediment concentrations during storm events vary somewhat from the observed values. The general nature of the sediment submodel shows promise of applicability to other regions, although experience is limited at the present time.

4. The PTR Model has demonstrated the capability of providing reasonable estimates of surface runoff and sediment loss from agricultural watersheds in the Southern Piedmont. These routes are the major modes of transport of pesticides and other non-point source pollutants to waterbodies. Consequently, further refinement of the pesticide functions (adsorption/desorption, volatilization, and degradation) will upgrade the capability of the model to predict the pesticide input to waterbodies from surface washoff. Moreover, the

Table 19. PESTICIDE MASS-BALANCE ON P1 WATERSHED
ON OCTOBER 30, 1972 (kg)

| | PARAQUAT | | DIPHENAMID | |
|---|---|---|---|---|
| | Field Measurement | Simulation | Field Measurement | Simulation |
| Application Amount* | 30.45 | - | 9.14 | - |
| Pesticide Lost by Runoff and Sediment | 2.097 | 1.915 | 0.082 | 0.104 |
| Degradation Loss** | - | 0.356 | - | 6.690 |
| Pesticide Remaining on Watershed | 29.96* | 28.23 | 2.33* | 2.39 |
| Mass Balance Error | +1.607 | | -6.728 | - |

* These values are affected by errors in equipment operation for application and problems of obtaining representative samples over the watershed.

** These values assume first order degradation with an empirical constant based on the pesticide remaining on the watershed on October 30, 1972.

PTR Model can provide the basis for the simulation of other non-point source pollutants (nutrients, fertilizers, etc.), and thus estimate the water quality of surface runoff from agricultural lands.

5. The loss of paraquat from the experimental watershed is simulated reasonably well by assuming complete adsorption onto sediment particles. Pesticides with a similar attraction to soil particles would likely produce similar results.

6. The single-valued (reversible) Freundlich adsorption isotherm appears to be inadequate in simulating the division between adsorbed and dissolved phases of diphenamid in runoff from the watersheds. This was also evidenced by the inability to simulate the observed vertical movement of the pesticides.

7. The observed variations in pesticide concentrations during runoff events appears to be of little consequence in predicting total pesticide loss; total mass movement of pesticide (grams/minute) past the gage during a storm event is a more valid comparison between simulated and observed pesticide loss.

8. Although simulated and recorded pesticide amounts remaining on the watersheds agreed reasonably well, concentrations within the soil profile were in error. The assumed depths of the soil zones is largely responsible for this discrepancy because the pesticide concentration is dependent on the total mass of soil in the zone.

## SECTION IX

## RECOMMENDATIONS FOR FUTURE RESEARCH

The subject research effort has produced a model which shows considerable promise in simulating the pesticide contribution to waterbodies by agricultural runoff. The PTR Model, developed on small agricultural watersheds, requires additional development and further refinement before it can be utilized in the regulation of pesticides released to the environment. In addition to internal improvements, suggested in the conclusions of Section I, complimentary research needs to be conducted to support the Model, if it is to be used in regulation.

One philosophy of regulation might involve the use of the PTR Model to estimate the fraction of applied pesticide that would reach the aquatic environment. Standards could be established denoting the maximum amount (or concentration) of pesticide that could be accepted by the aquatic environment without damage to man or the ecosystem. Such standards in conjunction with the fractions obtained from the PTR model could establish a maximum allowable pesticide application rate. To develop a viable methodology, such rates would have to be determined for groups of pesticides with similar toxicity and transport characteristics. Also, the rates would need to be evaluated under varying edaphic and climatic conditions across the country. In water quality management, a 'control point' or 'point of use' is often specified to establish standards of pollutant concentrations at a critical point in the watershed. Similarly in pesticide regulation, a control point would be necessary to specify at what point pesticides leave the agricultural field environment and enter the aquatic environment where substantial harm is possible. This would be necessary for regulation purposes. Intermittent streams, topography, and climatic conditions all contribute to the complexity of specifying a control point and the corresponding drainage area. The PTR Model would need to be run in various regions in order to determine the pesticide fractions for these control size watersheds which would likely vary across the country. The pesticide fractions, control-size watersheds, and pesticide standards would provide the basis for regulating pesticides releases to the environment.

Other philosophies of regulation might emphasize the need to control the concentrations of pesticides entering the aquatic ecosystem. The PTR Model could be used to estimate pesticide concentrations in agricultural runoff from certain storm events. Extended simulation runs of 20 or 30 years could provide frequency distributions of pesticide concentrations, which, in turn, would help to evaluate the risk of contamination. Hopefully, methodologies such as these would help to equitably compromise the concerns of the agriculturist and the ecologist. The use of pesticides needs to be regulated to provide efficient pest control without undue harm to the environment.

From the results and conclusions of the present research effort, and considering future uses of the PTR Model in pesticide regulation, the following recommendations are presented:

1. Continuous simulation of pesticide transport, as opposed to static steady-state investigations, has been shown to be a valid methodology for performing a materials balance of pesticides applied to agricultural lands. The dynamic nature of continuous simulation allows the full accounting of: (a) pesticides remaining on the land surface, (b) pesticide concentrations and volume lost during storm events, and (c) accumulated amounts of pesticide lost to the aquatic ecosystem during a growing season. Consequently this approach to the investigation of pesticide transport warrants further refinement.

2. An understanding of the mechanisms of surface runoff and sediment loss is paramount to the study of the importance of non-point source pollutants on water quality. The PTR Model has demonstrated the capability of representing these mechanisms. Consequently, the coupling of the PTR Model with additional pollutant attenuation, adsorption, and degradation functions could provide the structure for modeling the transport of plant nutrients, fertilizers, animal wastes, and other non-point source pollutants. The effects of silvicultural and agricultural management techniques on water quality could be evaluated through the PTR Model by their effect on the transport mechanisms of the non-point source pollutants. Development of such submodels needs to be undertaken in order to realize the full potential of the Model as a management tool.

3. For further refinement of the existing PTR Model, future research needs to be concerned with:

   a. additional testing and calibration of the hydrologic model to more accurately evaluate model algorithms and land surface parameters.

   b. calibration and possible refinement of the sediment loss model to better reproduce recorded sediment concentrations and to gain experience with the sensitivity of the sediment loss parameters.

   c. refinement and testing of the adsorption-desorption model to better determine the division between the adsorbed and dissolved phases of pesticides which are transported on both sediment and water. The inclusion of a nonsingle-valued adsorption-desorption model warrants further investigation. These refinements are critical to the reliable prediction of pesticide lost in water and on sediment during storm events.

d. additional development and testing of the volatilization and degradation models on actual field data, so that an accurate pesticide materials balance can be performed. The effects of environmental factors on these mechanisms needs to be investigated.

4. To determine the general applicability of the PTR Model, the following tasks are recommended:

a. Calibration and testing of the Model for runoff and sediment loss on watersheds in various regions of the country. This would allow investigation of changes in parameter values with varying soil and climatic characteristics, and would demonstrate the behavior of the Model under varying conditions.

b. Evaluation of model performance on watersheds ranging from 20 to 200 hectaries in order to determine required improvements in the Model for larger watersheds. This would provide insight into the effects of channel processes on runoff and sediment loss, and demonstrate the efficacy of existing model algorithms to simulate the hydrologic and erosion processes.

5. If the PTR Model is to be considered as a tool for regulating the release of pesticides, the following areas need to be investigated:

a. determination and definition of control-size watersheds in various regions of the country which would be most amenable to pesticide release regulations.

b. classification and grouping of pesticides according to toxicity, transport, and persistence characteristics

c. establishment of maximum seasonal releases of pesticides within each classification which would not inflict serious consequences on man or the aquatic ecosyste. The fractions of applied pesticides which reach waterbodies could then be evaluated by the PTR Model and provide a basis for regulating pesticide releases.

# SECTION X

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# SECTION XI

# APPENDICES

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# APPENDIX A

## DESCRIPTION OF HSP LANDS*

Figure 27 presents the flowchart of the HSP LANDS program. The hydrologic processes and functions sketched are discussed in the following sections.

### INTERCEPTION

The first loss to which falling precipitation is subjected is interception, or retention on leaves, branches and stems of vegetation. Interception in any single storm is small in amount and is not important in flood producing storms. However, in the aggregate interception may have a significant effect on annual runoff.

In nature, interception is a function of the type and extent of vegetation and, for deciduous vegetation, the season of the year. In HSP, interception is modeled by defining an interception storage capacity EPXM+ as an input parameter. All precipitation is assumed to enter interception storage until it is filled to capacity. Water is removed from interception storage by evapotranspiration at the potential rate. Evapotranspiration may occur even during rain so that after the storage is filled there is a continuing interception equal to the potential evapotranspiration.

### IMPERVIOUS AREA

Precipitation on impervious areas that are adjacent to or connect with stream channels will contribute directly to surface runoff. An input parameter+ A in HSP represents this "impervious" fraction of the total watershed area. Precipitation minus interception is multiplied by the impervious area fraction to determine the impervious area contribution to streamflow.

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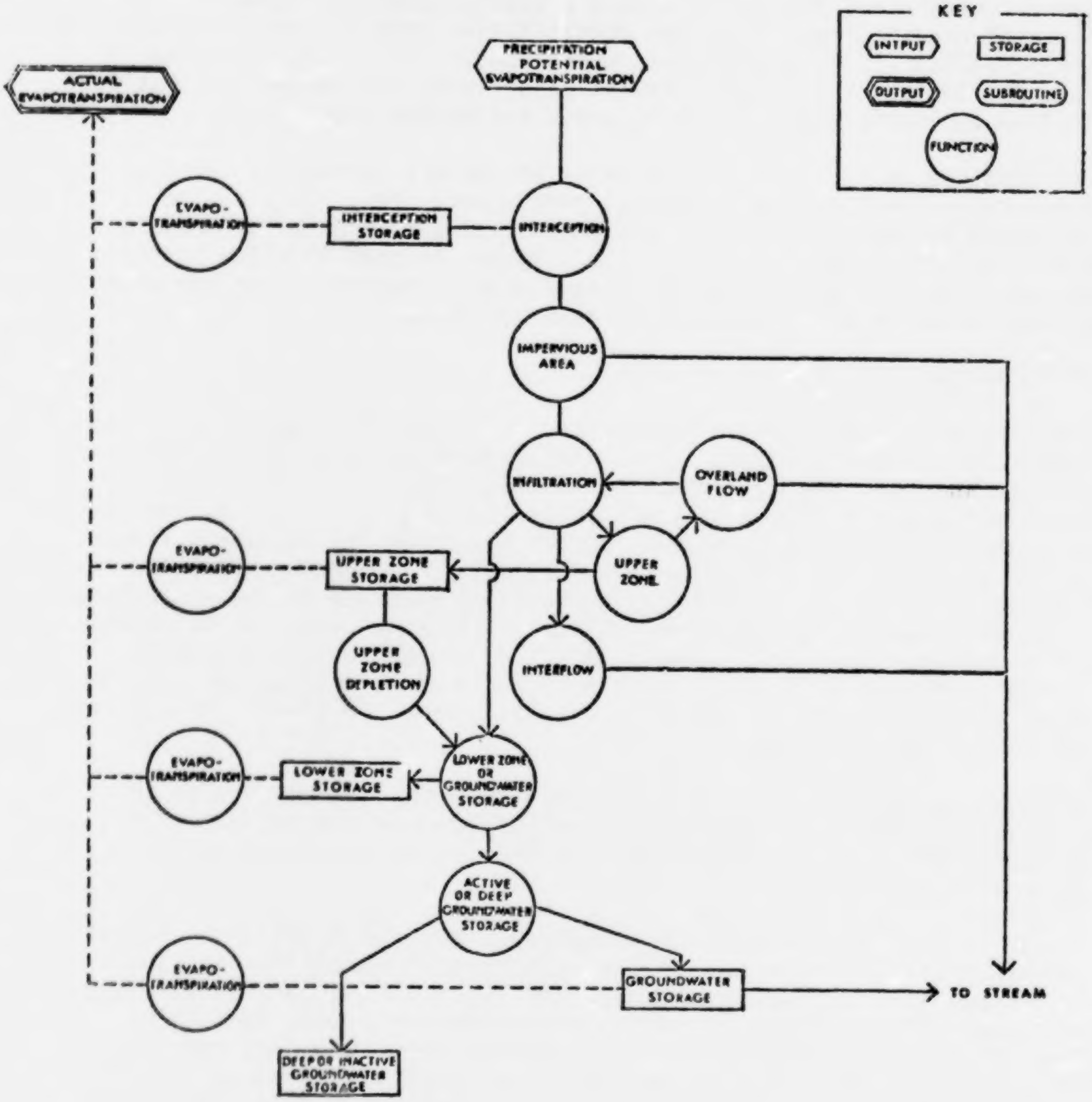
*This appendix is abstracted directly from the Hydrocomp Operations Manual[15]

+Input parameters appear in uppercase roman letters.

Reproduced from best available copy.

Figure 27 Lands flowchart


KEY
INPUT
STORAGE
OUTPUT
SUBROUTINE
FUNCTION
ACTUAL EVAPOTRANSPIRATION
PRECIPITATION POTENTIAL EVAPOTRANSPIRATION
EVAPO-TRANSPIRATION
INTERCEPTION STORAGE
INTERCEPTION
IMPERVIOUS AREA
INFILTRATION
OVERLAND FLOW
EVAPO-TRANSPIRATION
UPPER ZONE STORAGE
UPPER ZONE
UPPER ZONE DEPLETION
INTERFLOW
EVAPO-TRANSPIRATION
LOWER ZONE STORAGE
LOWER ZONE OR GROUNDWATER STORAGE
ACTIVE OR DEEP GROUNDWATER STORAGE
EVAPO-TRANSPIRATION
GROUNDWATER STORAGE
TO STREAM
DEEP OR INACTIVE GROUNDWATER STORAGE

| PESTICIDE RUNOFF | Hydrocomp |
|---|---|

The impervious area is usually a very small percentage of the total watershed, except in urban areas. In rural watersheds impervious area does not contribute large amounts of runoff. However, for the light rains with relatively dry soil impervious area may be the sole contribution of runoff to the stream. During the calibration phase the impervious area term is usefull in reproducing these small runoff events. It enhances the detailed understanding of the hydrologic process during simulation. In urban areas the "impervious area" term becomes very important.

Lakes, swamps, and reservoirs create a special class of impervious area. "Runoff" results from all of the precipitation that reaches these surfaces and potential (lake) evaporation occurs continuously. The parameter A does not include the surface area of major lakes and reservoirs, but does include the surface area of small ponds and stream channels.

Calculations in the land surface phase of HSP are carried in terms of water depth (inches or millimeters) over a unit area. Only at the beginning of the channel phase are these depths multiplied by area to derive actual volumes of runoff. This system is used to allow investigation of various amounts of impervious area or reservoir surface area without altering the response from pervious areas.

## INFILTRATION

The process of infiltration is essential and basic to simulation of the hydrologic cycle. Infiltration is the movement of water through the soil surface into the soil profile. Infiltration rates are highly variable and change with the moisture content of the soil profile, and infiltration is the largest single process diverting precipitation from immediate streamflow. Usually more than half of the water which infiltrates is retained in the soil until it is returned to the atmosphere by evapotranspiration. However, not all infiltrated water is permanently diverted from streamflow. Some infiltrated water may move laterally through the upper soil to the stream channels as interflow, and some may enter temporary storages and later discharge into the stream channels as base or groundwater flow.

Water which does not infiltrate directly into the soil moves over the land surface and is subject to delayed infiltration and retention in surface depressions. The delayed infiltration is introduced by the upper zone function.

The infiltration capacity, the maximum rate at which a soil will accept infiltration, is a function of fixed characteristics of the watershed-soil type, permeability, land slopes and vegetal cover; and of variable characteristics - primarily soil moisture content. Soils containing clay colloids may expand as moisture content increases, thus reducing pore space and infiltration capacity. The actual infiltration rate at a point at any time is equal to the infiltration capacity or the supply rate (precipitation minus interception plus surface detention), which-ever is least.

Traditionally infiltration has been represented by an infiltration capacity curve in which the capacity is an exponential function of time. This is in accord with experimental evidence provided the supply rate always exceeds the capacity. Since supply rates are frequently less than infiltration capacity, the variation of infiltration capacity is controlled by accumulation of soil moisture and may not be described by any smooth function of time.

Infiltration relationships used for continuous simulation must:

(1) Represent segment mean infiltration rates continuously. Since variable moisture supply rates preclude continuous functions of time, expressions for infiltration as a function of soil moisture content are used. (Note: A segment is a portion of a watershed with uniform climatic and hydrologic characteristics.)

(2) Represent the areal variation in infiltration - the distribution of infiltration capacities that will exist at any time about the segment average.

To meet requirement (1) HSP uses a method based on infiltration equations developed by Phillips[49].

$$F = st^{\frac{1}{2}} + at \tag{14}$$

$$f = \frac{st^{-\frac{1}{2}}}{2} + a \tag{15}$$

Where F is cumulative infiltration, f is infiltration rate, and t is time. The letters a and s are constants that depend on soil properties.

If the constant a is small Eqns. (14) and (15) can be written:

$$fF = \frac{s^2}{2} \tag{16}$$

Since $s^2/2$ is constant, Eqn. (16) continuously relates infiltration rate to cumulative infiltration or infiltrated volume. This is the type of relation needed in hydrologic simulation.

Equation (16) will apply only approximately to intermittent infiltration when the moisture distribution in the soil profile adjusts between rains. Homogeneous soil is also assumed but a decrease in permeability as depth increases is more common. Therefore Eqn. (16) is modified to:

$$fB^b = \text{constant} \tag{17}$$

where b is a constant greater than one. Numerous trials have resulted in adoption of b = 2 as a standard value in HSP.

The second requirement listed above, representation of areal variations in infiltration capacity, has not normally been considered in applications of the infiltration concept. Areal variation results from differences in soil type and permeability and from differences in soil moisture which in turn result from differing vegetal cover, precipitation, and exposure to evaporation. It can be expected that the infiltration capacities that exist from point to point in a watershed at a given time will have some distribution about a mean value (Fig. 28). The corresponding cumulative infiltration capacity curve (Fig. 29) is of interest as a basis for runoff volume calculations. The solid line sketched in Fig. 29 is plotted from the example of an actual frequency distribution sketched in Fig. 28.

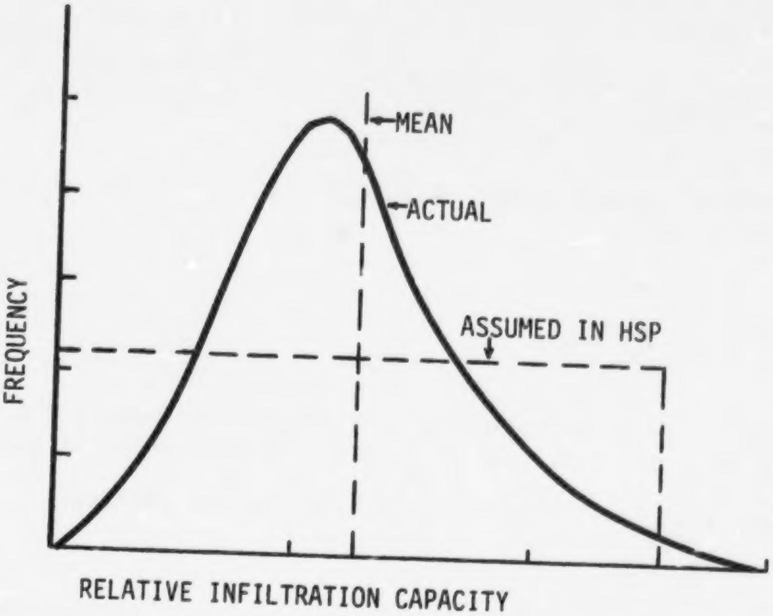


Figure 28. Schematic frequency distribution of infiltration capacity in a watershed

The shape of the cumulative frequency distribution that will apply in a watershed at any time is impractical to determine, and for mathematical simplification the dashed line in Fig. 29, corresponding to the dashed frequency distribution in Fig. 28, is assumed in HSP. The assumption of a linear variation is reasonably well verified by the limited experimental data that is available, and experience indicates that the assumption yields satisfactory results.

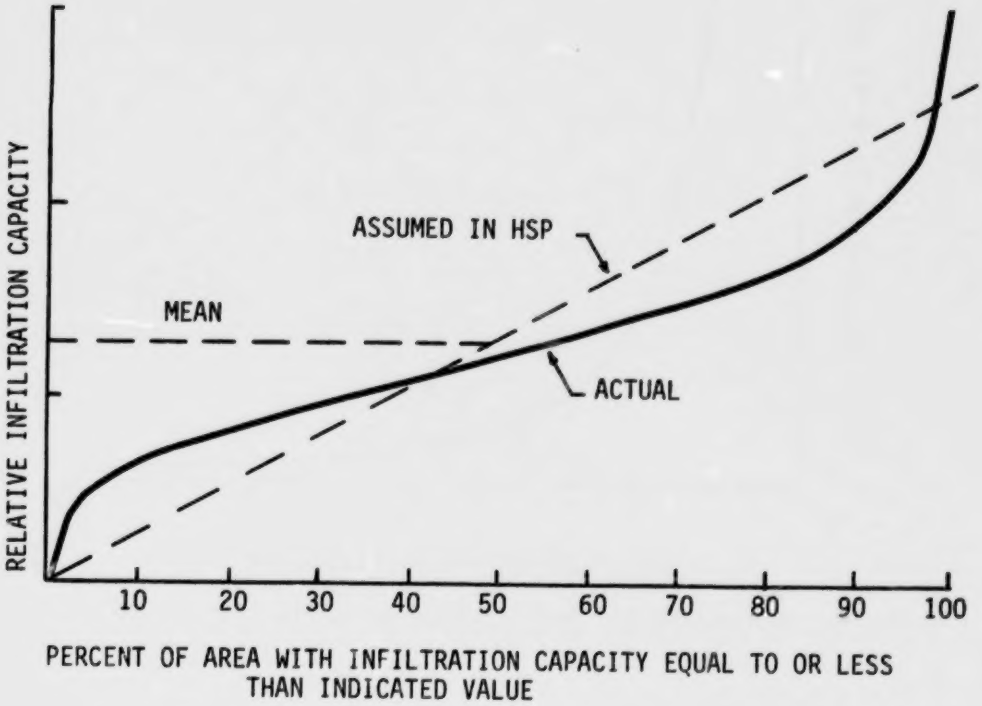


Figure 29. Cumulative frequency distribution of infiltration capacity

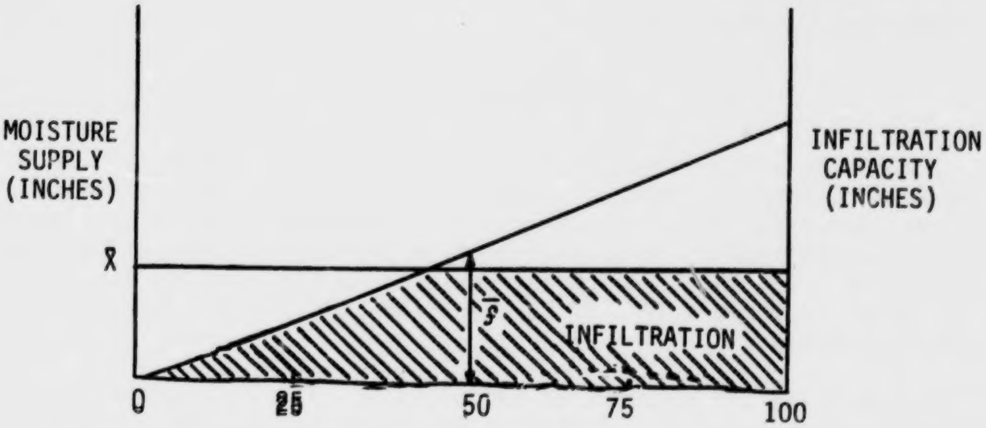

MOISTURE SUPPLY (INCHES)
INFILTRATION CAPACITY (INCHES)
X̄
S̄
INFILTRATION
0
25
50
75
100

Figure 30. Application of cumulative frequency distribution of infiltration capacity in HSP

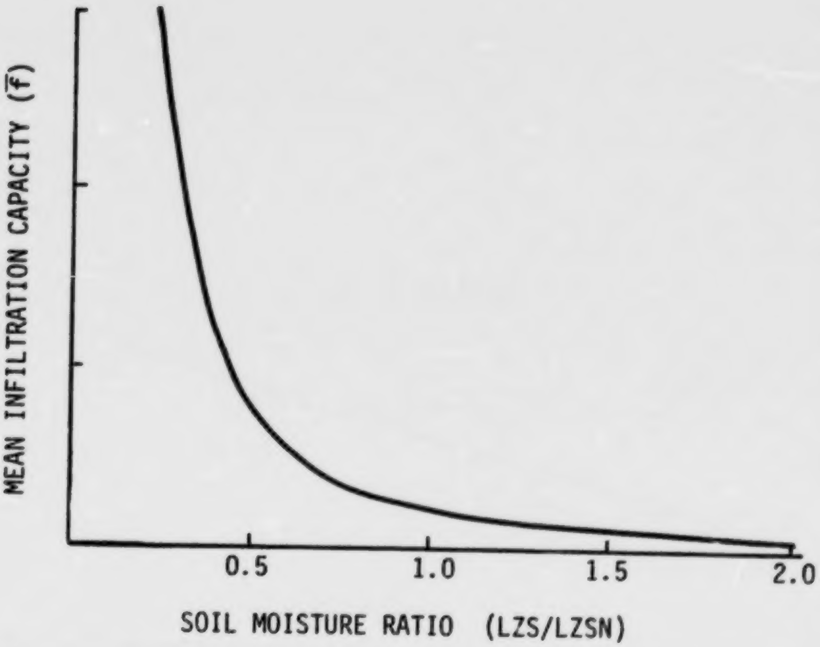


Figure 31. Mean watershed infiltration as a function of soil moisture

The results of the assumptions developed above are illustrated in Fig. 30. Rainfall or snowmelt gives a moisture supply of $\overline{x}$ inches in a certain time interval. The cross hatched area in Fig. 30 represents the infiltration that is added to soil moisture or groundwater storage in the time interval.

The mean infiltration capacity $\overline{f}$ is time-variable, decreasing as infiltration increases the soil moisture content. The value of $\overline{f}$ is calculated based on Eqn. (17) as:

$$\overline{f} = \text{INFILTRATION}/\ (\text{LZS}/\text{LZSN})^2 \qquad (18)$$

LZS/LZSN is a dimensionless soil moisture storage ratio, LZS is the current storage in the soil profile, and LZSN (an input parameter) is an index level for moisture storage. INFILTRATION is an input parameter that establishes an index infiltration level, and is equal to $\overline{f}$ where LZS/LZSN = 1. INFILTRATION is shortened to INFIL in the PTR LANDS subprogram. Numeric values of LZSN and INFILTRATION are discussed later in this appendix.

To illustrate the sequence of calculations for time dependence of infiltration consider that rainfall causes the moisture supply $\overline{x}$ in Fig. 30

in a given time interval. Infiltration occurs and the variable soil moisture storage LZS increases. In the next time interval $\bar{f}$ will decrease since LZS/LZSN in Fig. 31 has increased. The combination of functions represented by Figures 30 and 31 simulates the complex time and areal variation of infiltration over a segment of a watershed. Since different parameters may be used in each segment of a watershed large variations in topography and soil properties can be represented. Simulation algorithms make infiltration a function of the supply rate and vary the area contributing to runoff continuously.

## INTERFLOW

Infiltration may lead to interflow, runoff that moves laterally in the soil for some part of its path toward a stream channel. Interflow is encouraged by any relatively impermeable soil layers and has been observed to follow roots and animal borrows in the soil. Interflow may come to the surface to join overland flow if its flow path intersects the surface. Fig. 30 is extended (Fig. 32) to represent interflow by adding a line to represent transient infiltration for the interflow process. The variable c is defined by:

$$c = \text{INTERFLOW} \times 2^{(\text{LZS/LZSN})} \qquad (19)$$

an empirical equation that results in the variation with soil moisture sketched in Fig. 33. INTERFLOW is an input parameter that governs the volume assigned to interflow. INTERFLOW is shortened to INTER in the PTR LANDS sub-program.

This simulation scheme makes interflow a function of the local infiltration rate and of soil moisture. That is, the higher the soil moisture the greater the fraction of infiltration which becomes interflow. The combination of interflow and infiltration functions yields a smooth response to variations in moisture supply in any time interval. Fig. 34 illustrates this response.

## UPPER ZONE

Moisture that is not infiltrated directly will increase surface detention storage. The increment to surface detention calculated from Fig. 32 will either contribute to overland flow or enter upper zone storage. Depression storage and storage in highly permeable surface soils are modelled by the upper zone. The upper zone inflow percentage P is independent of rainfall intensity but upper zone storage capacity is low. Moisture is lost from the upper zone by evaporation and percolation to the lower zone and groundwater storages.

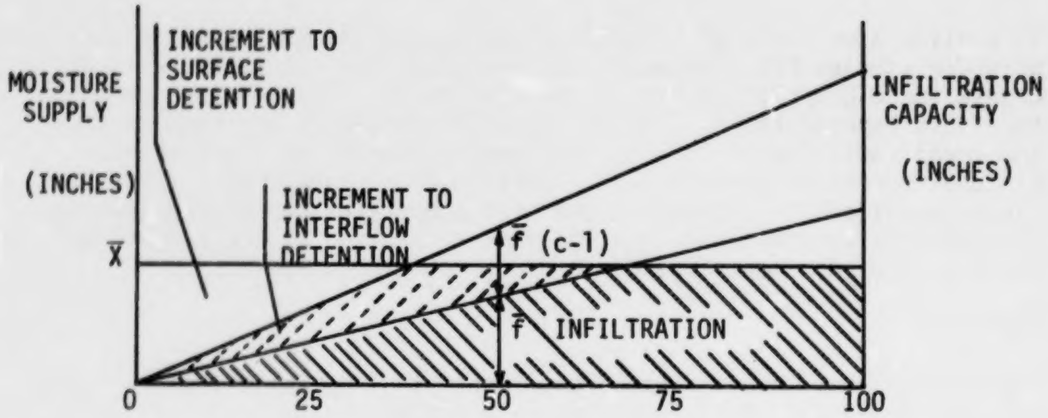

MOISTURE SUPPLY
(INCHES)
INCREMENT TO SURFACE DETENTION
INCREMENT TO INTERFLOW DETENTION
$\bar{X}$
$\bar{f}$ (c-1)
$\bar{f}$
INFILTRATION
INFILTRATION CAPACITY
(INCHES)
0
25
50
75
100

Figure 32. Cumulative frequency distribution of infiltration capacity showing infiltration volumes, interflow and surface detention

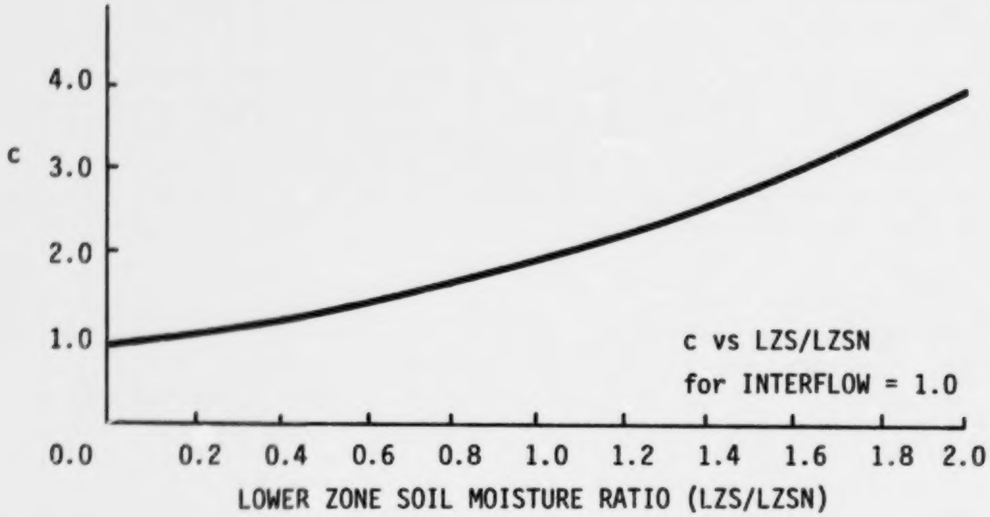


Figure 33. Interflow c as a funtion of LZS/LZSN

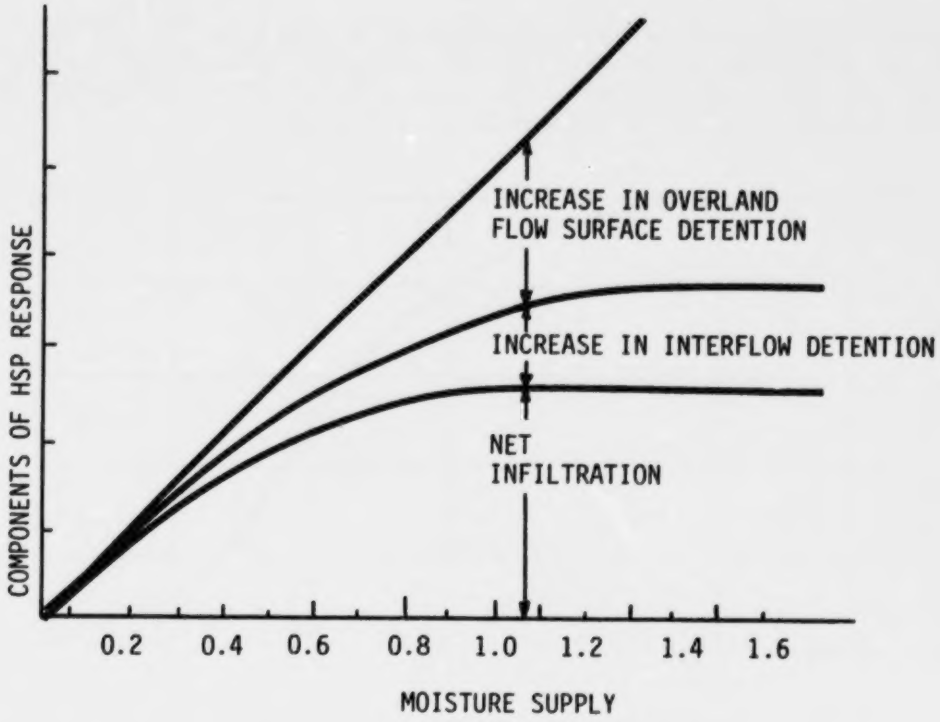


Figure 34. Components of HSP response vs. moisture supply

The following expressions are used to calculate the response of the upper zone storage. The upper zone has a nominal capacity given by the input parameter UZSN. The percentage P of a potential addition to overland flow surface detention that is held in the upper zone is a function of the upper zone storage UZS and the nominal capacity UZSN (Fig. 35). When the ratio UZS/UZSN is less than two,

$$\underline{P} = 100 \left\{ 1.0 - \left(\frac{UZS}{2 \times UZSN}\right) \times \left(\frac{1.0}{1.0 + k_1}\right)^{k_1} \right\} \qquad (20)$$

$$\text{Where } k_1 = 2.0 \left| \left(\frac{UZS}{2 \times UZSN}\right) - 1.0 \right| + 1.0 \qquad (21)$$

When UZS/UZSN is greater than two the percentage is given by

$$\underline{P} = 100 \left(\frac{1.0}{1.0 + k_2}\right)^{k_2} \qquad (22)$$

Where $k_2$ is

$$k_2 = 2.0 \left| (UZS/UZSN) - 2.0 \right| + 1.0 \qquad (23)$$

The upper zone storage prevents overland flow from a portion of the watershed depending on the value of the ratio UZS/UZSN, but since the nominal capacity UZSN is small, the upper zone retention percentage decreases rapidly with early increments of accretion.

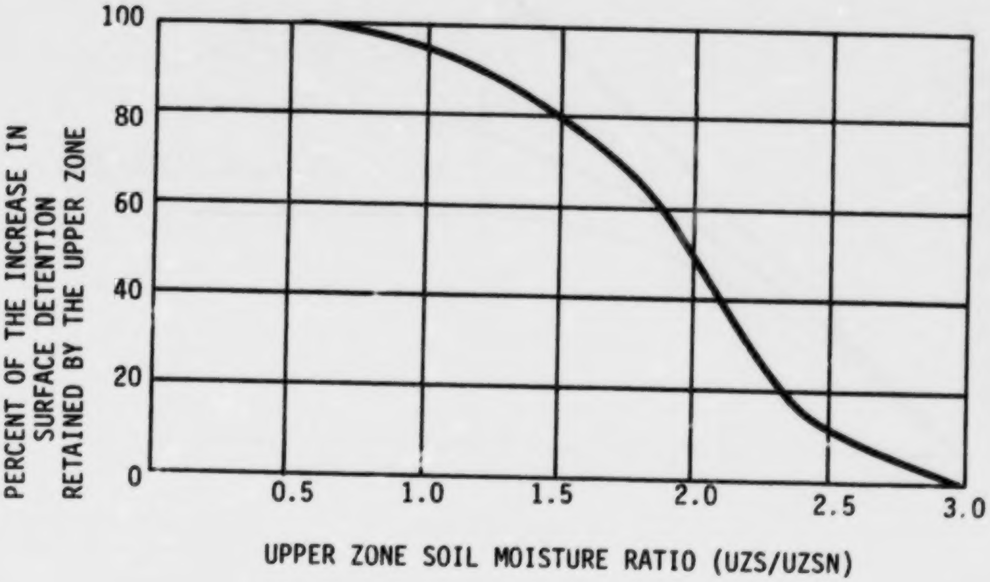


Figure 35. Surface detention retained in the upper zone

Percolation (PERC) occurs from the upper zone to the groundwater and lower zone storages when the upper zone storage ratio UZS/UZSN exceeds the lower zone storage ratio LZS/LZSN. This is calculated as

$$PERC = 0.1 \times INFILTRATION \times UZSN \times \left[(UZS/UZSN) - (LZS/LZSN)\right]^{3} \qquad (24)$$

where INFILTRATION is the infiltration level input parameter and PERC is the percolation rate in inches/hour. Evapotranspiration occurs from the upper zone storage at the potential rate of UZS/UZSN is greater than 2.0. If UZS/UZSN is less than 2.0 the portion of the potential evapotranspiration (PET) that is satisfied by upper zone is given by

$$ET\ (actual) = 0.5\ (UZS/UZSN) \times PET \qquad (25)$$

Potential evapotranspiration that is not assigned to the upper zone is passed to the lower zone. The assignment from Eqn. 25 models direct evaporation from near-surface soil. Moisture loss from the lower zone models transpiration by vegetation.

The use of a nominal rather than an absolute capacity for the upper zone storage permits a smooth increase in overland flow rates as upper zone storage increases. If an absolute capacity were used, there would be an abrupt increase in overland flow when the capacity was attained. Such an abrupt change is not consistent with experience nor with the observation that a truly "saturated" state is rarely, if ever, observed. Because of the use of a nominal capacity it is not possible to define upper zone storage in any rigorous physical sense. It is best viewed as an input parameter representing moisture retention at and near the soil surface.

## OVERLAND FLOW

The movement of water in surface or overland flow is an important land-surface process. Interactions between overland flow and infiltration need to be considered since both processes occur simultaneously. The variations in rates of infiltration described above allow overland flow in areas with low infiltration while preventing overland flow in other areas. During overland flow, water held in detention storage remains available for infiltration. Surface conditions such as heavy turf or very mild slopes that restrict the velocity of overland flow tend to reduce the total quantity of runoff by allowing more time for infiltration. Short, high intensity rainfall bursts are attenuated by surface detention storage reducing the maximum outlow rate from overland flow.

A wide range of methods for the calculation of unsteady overland flow were considered. The only rigorous general methods for simulating unsteady overland flow are finite difference techniques for the numerical solution of the partial differential equations of continuity and momentum. These methods have a major disadvantage for continuous simulation since substantial amounts of computer time are needed. In a natural watershed there are areal variations in the amount of runoff moving in overland flow because of areal variations in infiltration. Average values must be used in the calculations for the length, slope, and roughness of overland flow. Hence the accuracy gained by using finite difference methods for overland flow is subject to question because of the limitations on the input data.

In HSP, overland flow is treated as a turbulent flow process. Since continuous surface detention was chosen as the parameter to be related to overland flow discharge. Using the Chezy-Manning equation, the relation between surface detention storage at equilibrium $D_e$, the supply rate to overland flow i, Manning's n and the length L and slope S of the flow plane is

$$D_e = \frac{0.000818 i^{0.6} n^{0.6} L^{1.6}}{S^{0.3}} \qquad (26)$$

Using the ratio of detention depth at any instant to detention depth at equilibrium $D_e$ as an index of the distribution of flow over the overland plane, an empirical expression relating outflow depth and detention storage which fits experimental data quite well is

$$y = \frac{D}{L} \times \left[1.0 + 0.6 \left(\frac{D}{D_e}\right)^3\right] \qquad (27)$$

Sustituting Eqn. (27) in the Chezy-Manning Equation the rate of discharge from overland flow in $ft^3/sec/ft$ is

$$q = \frac{1.486}{n} S^{\frac{1}{2}} \left(\frac{D}{L}\right)^{5/3} \left[1.0 = 0.6 \left(\frac{D}{D_e}\right)^3\right]^{5/3} \qquad (28)$$

where $D_e$ is a function of the current supply rate to overland flow and is calculated from Eqn. (26). During recession flow when $D_e$ is less than D the ratio $D/D_e$ is assumed to be one. HSP continuously solves a continuity equation

$$D_2 = D_1 + \Delta D - \bar{q} \Delta t \qquad (29)$$

where $\Delta t$ is the time interval used, $D_2$ is the surface detention at the end of the current time interval, $D_1$ is the surface detention at the end of the previous time interval, $\Delta D$ is the increment added to surface detention in the time interval, and $\bar{q}$ is the overland flow into the stream channel during the time interval. The discharge $\bar{q}$ is a function of the moisture supply rate and of $(D_1 + D_2)/2$, the average detention storage during the time interval (D in Eq. (28).

The system of equations can be solved numerically with good accuracy if the time interval of the calculation is sufficiently small so that the value of discharge in any time interval remains a small fraction of the volume of surface detention. Calculations of discharge from overland flow are made on a 15-minute time interval, but shorter time intervals can be used if required by the characteristics of the flow plane, or if justified by the input data.

The overland flow calculations enter the delayed infiltration process through the fact that any water remaining in detention at the end of an interval is added to the rainfall minus interception of the next period to give the supply rate for the infiltration calculations. Overland flow detention is an important part of the total delay time in runoff on small watersheds. Figures 36 and 37 illustrate the "fit" of the HSP simulation of overland flow to experimental data. Fig. 38 shows that on a watershed of 0.26 square miles, overland flow simulation closely approximates the actual outflow hydrograph indicating that overland flow delay is much more important than channel storage in controlling hydrograph shape. Fig. 39 shows a similar comparison for a watershed of 18.5 square miles which is partly urbanized. Here, the overland flow effects on hydrograph shape are relatively small although the effect through delayed infiltration is still present.

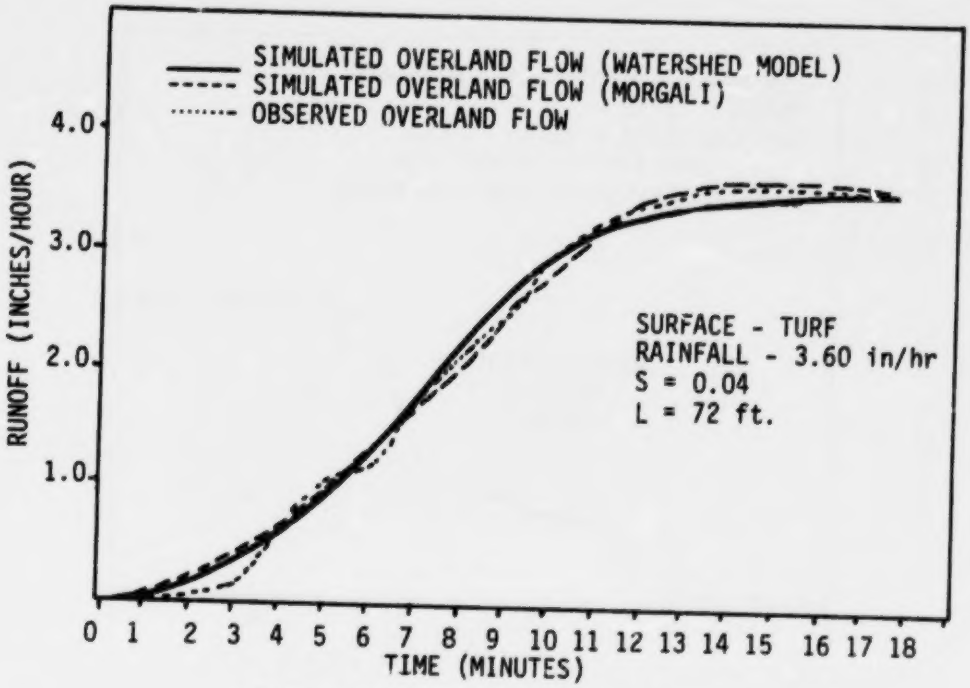


Figure 36. HSP Overland flow simulation

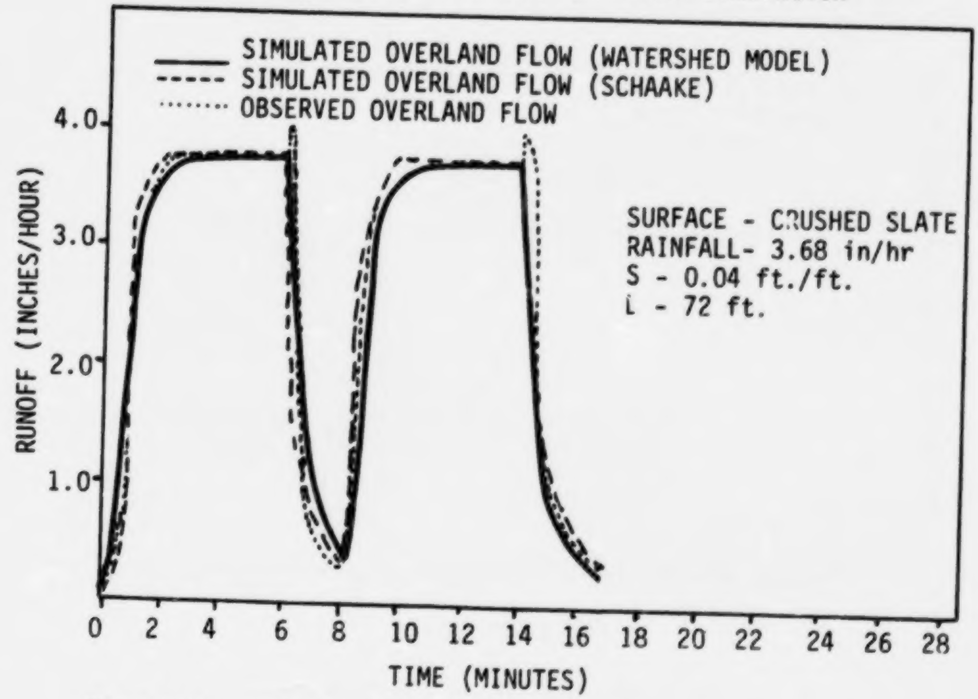


Figure 37. HSP Overland flow simulation

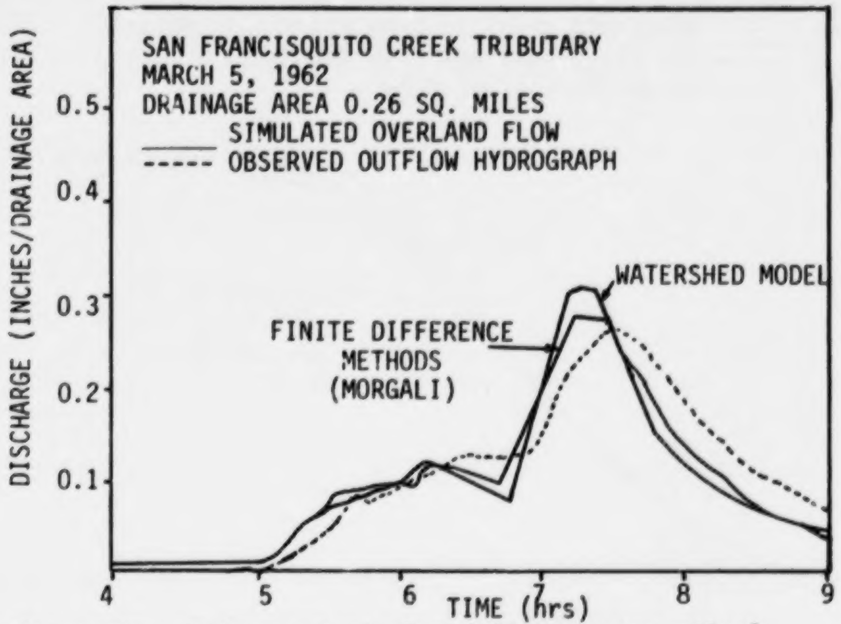


Figure 38. Hydrograph simulated (0.26 square miles)

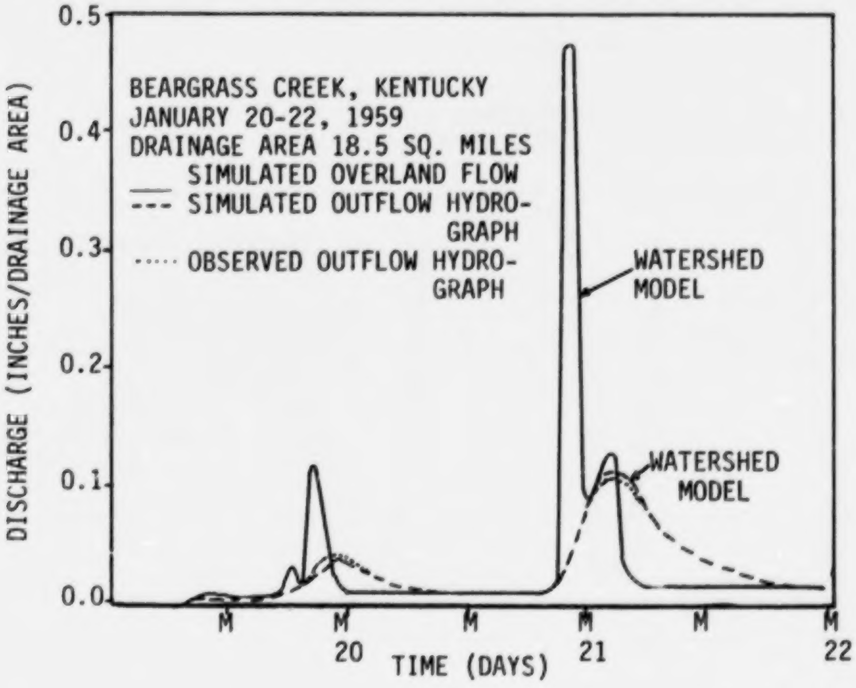


Figure 39. Hydrograph simulation (18.5 square miles)

## INTERFLOW STORAGE

The calculation of an increment to interflow detention storage SRGX was described in Sec. 1.5. Outflow from this storage to the stream is calculated on a 15-minute time interval by the equation

$$\mathrm{INTF} = \mathrm{LIRC4} \times \mathrm{SRGX} \qquad (30)$$

where

$$\mathrm{LIRC4} = 1.0 - (\mathrm{IRC})^{1/96} \qquad (31)$$

IRC, an input parameter, is the daily recession constant for the interflow discharge at any instant to the interflow discharge twenty-four hours earlier.

## LOWER ZONE AND GROUNDWATER STORAGE FUNCTION

This function operates on the direct or immediate infiltration (Fig. 32) and the percolation from upper zone storage (PERC in Eqn. 24). The available water is divided between the lower zone or soil moisture storage and the groundwater storage. The division is based on the lower zone storage ratio LZS/LZSN where LZS is the quantity of moisture in the lower zone storage and LZSN is the lower zone nominal capacity. The percentage of the infiltration plus percolation that enters groundwater storage (Fig. 40) is given by

$$P_g = 100 \frac{\mathrm{LZS}}{\mathrm{LZSN}} \left(\frac{1.0}{1.0 + z}\right)^z \qquad (32)$$

when LZS/LZSN is less than one and by

$$P_g = 100 \left\{1.0 - \left(\frac{1.0}{1.0 + z}\right)^z\right\} \qquad (33)$$

when LZS/LZSN is greater than one. z is defined by

$$z = 1.5 \left| \frac{\mathrm{LZS}}{\mathrm{LZSN}} - 1.0 \right| + 1.0 \qquad (34)$$

These relationships are plotted in Fig. 40.

## LOWER ZONE STORAGE

The lower zone storage is the main moisture storage for the land surface in HSP. Like the upper zone storage it is defined in terms of a nominal capacity LZSN, the storage level at which half of the incoming infiltration enters the lower zone and half moves to groundwater. This use of a nominal rather than an absolute capacity serves the same

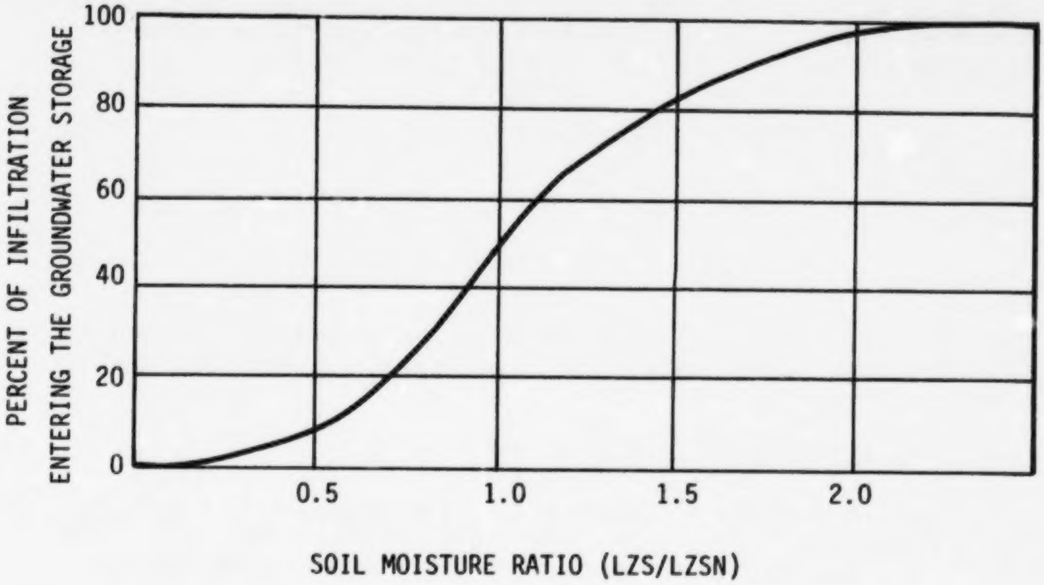


Figure 40. Infiltration entering groundwater storage

purpose as for the upper zone -- it avoids the abrupt change which would occur if an absolute capacity were reached, and permits a smooth transition in hydrologic performance as the lower zone storage increases.

Physically the lower zone may be viewed as the entire soil from just below the surface down to the capillary fringe above the water table. In practice we are concerned only with the transient portion of this storage--the volume which is emptied by evapotranspiration and refilled by infiltration. Consequently numerical values of the input parameter LZSN do not necessarily reflect the total moisture storage capacity of the lower zone.

## GROUNDWATER

Equations (32) and (33) determine the accretion to groundwater in each time increment. If some part of this water is believed to percolate to deep groundwater storage, this is modeled by allowing a fixed percentage of the inflow to groundwater to bypass the active groundwater storage and proceed directly to the deep or inactive storage. This portion is assigned by the input parameter K24L. Water assigned to deep groundwater is lost from the surface phase of the hydrologic cycle of the watershed segment. It may leave the basin as subsurface flow but it does not contribute to streamflow.

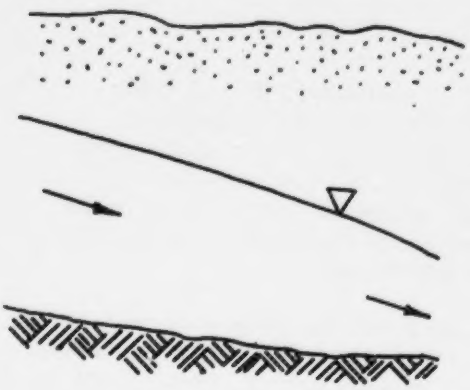


Figure 41. Groundwater flow

The outflow from active groundwater storage at any time is based on the simplified model in Fig. 41. The discharge of an aquifer is proportional to the product of the cross-sectional area and the energy gradient of the flow. A representative cross-sectional area of flow is assumed proportional to the groundwater storage level computed by HSP.

The energy gradient is estimated as a basic gradient plus a variable gradient that depends on groundwater accretion. The groundwater outflow GWF at any time is given by

$$GWF = LKK4 \times (1.0 + KV \quad GWS) \times SGW \qquad (35)$$

where GWS is groundwater slope and SGW is groundwater storage. The variable GWS is an antecedent index based on inflow to groundwater storage and is calculated daily as

$$GWS = 0.97\ (GWS + \text{inflow to groundwater storage}) \qquad (36)$$

Groundwater outflow is calculated on 15-minute intervals. The identifier LKK4 is defined as

$$LKK4 = 1.0 - (KK24)^{1/96} \qquad (37)$$

where KK24 is the minimum observed daily recession constant of groundwater flow, the ratio of current groundwater discharge to the groundwater discharge twenty-four hours earlier. When the parameter KV is zero and inflow to groundwater storage is zero, Eqn. (35) reproduces the commonly used logarithmic depletion curve, i.e., the flow after a period of n days decreases by $(KK24)^n$, and a semi-logarithmic plot of discharge vs. time is a straight line.

KV is introduced to allow variable groundwater recession rates. When KV is non-zero a semi-log plot of discharge vs. time is not linear. For example, if the typical daily dry-season recession rate in a stream is 0.99 and a recession of 0.98 is more typical when groundwater storages are being recharged, the value of KK24 can be set to 0.99 and the value of the parameter KV can be adjusted so that $1.0 + KV \times GWS$ will reduce the effective recession rate to 0.98 during recharge periods. This added flexibility in groundwater outflow simulation, introduced at the cost of an additional input parameter, is useful in many watersheds.

## EVAPOTRANSPIRATION

The volume of water that leaves a watershed as evaporation and transpiration exceeds the total volume of stream flow in most hydrologic regimes. Continuous estimates of actual evapotranspiration must therefore be made by HSP. There are two separable issues involved in estimating actual evapotranspiration. Potential evapotranspiration must be selected, and actual evapotranspiration must be calculated as a function of moisture conditions and the potential evapotranspiration.

Potential evapotranspiration is assumed to be equal to lake evaporation estimated from U.S. Weather Bureau Class A pan records[50]. This procedure is more convenient than an approach based on meteorological data since input requirements are less stringent. A single variable, adjusted pan evaporation data, serves a purpose that would otherwise require input of several variables. If pan evaporation data are not available, the input data for potential evapotranspiration may be estimated by an appropriate method. The relationship of actual evapotranspiration to potential evapotranspiration over large areas should logically be a function of moisture conditions. Even if transpiration from vegetation is independent of soil moisture until the wilting point is reached, variable soil moisture will cause wilting in some parts of a watershed but not in others. Evaporation from soil, a component of the total process, is dependent on moisture conditions.

When near surface storage is depleted, the concept of evapotranspiration opportunity is defined as the maximum quantity of water accessible for evapotranspiration in a time interval at a point in the watershed. It is analogous to infiltration capacity and would have a cumulative distribution similar to that in Fig. 29. The cumulative evapotranspiration opportunity curve will be a function of watershed soil moisture conditions, and will give estimates of actual evapotranspiration for any quantity of potential evapotranspiration, just as the cumulative infiltration capacity curve estimates net infiltration for any moisture supply.

Evapotranspiration occurs from interception storage at the potential rate. Evapotranspiration opportunity controls evapotranspiration from the lower zone storage. Evaporation from streams and reservoir surfaces, and evapotranspiration from groundwater storages is also simulated. Daily lake evaporation or potential evapotranspiration data, or average daily rates for semi-monthly periods are used as input. HSP computes hourly values from the daily totals using an empirical diurnal variation.

Potential evapotranspiration will result in a water loss or actual evapotranspiration only if water is available. HSP first attempts to satisfy the potential from interception storage and from the upper zone in that order. The contribution to actual evapotranspiration of the upper zone is limited if UZS/UZSN is less than 2.0 (Eq. 25). Any remaining potential enters as $E_p$ in Fig. 42. Since evapotranspiration opportunity in a watershed on a given day may be expected to vary through a considerable range, a cumulative frequency distribution similar to those found for infiltration capacity in Fig. 30 might be reasonable. Following the assumption made for infiltration capacity the cumulative frequency distribution of evapotranspiration opportunity is assumed to be linear (Fig. 42)

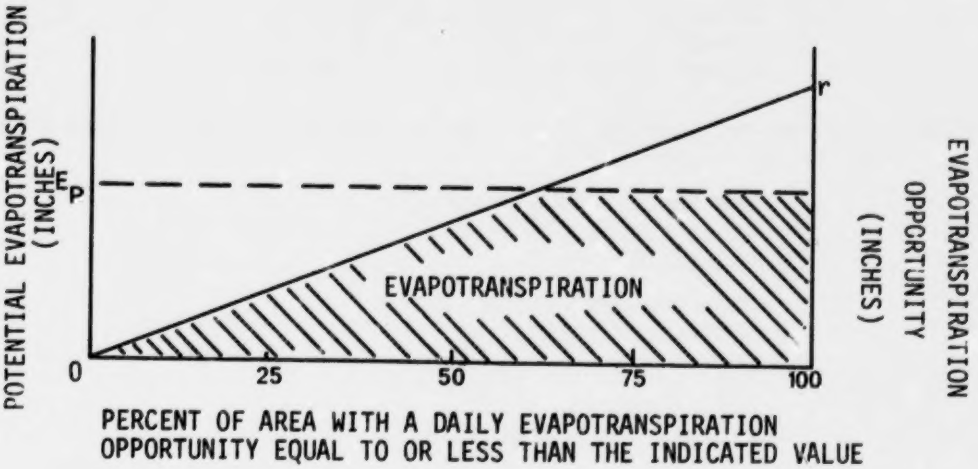


Figure 42. Potential and actual evapotranspiration

The quantity of water lost by evapotranspiration from the lower zone when $E_p$ is less than r is given by the cross-hatched trapezoid of Fig. 42. The variable r is an index given by

$$r = \left(\frac{0.25}{1.0 - K3}\right) \times \left(\frac{LZS}{LZSN}\right) \tag{38}$$

Evapotranspiration is further limited when K3 is less than 0.5. A fraction of the segment area given by 1.0-2xK3 is considered devoid of vegetation that can draw from the lower zone storage. K3 is an input parameter that is an index to vegetation density.

## PARAMETER EVALUATION

The process of applying LANDS to a watershed requires a fitting or calibration of parameters for the specific watershed. Some parameters are measured directly from topographic maps, or are easily found by conventional hydrologic procedures. Other parameters are established by computer runs. Numerical values for the LANDS parameters are required for each simulation trial. Methods for estimating these parameters follow:

A: A is the fraction representing the impervious area in a segment. Usually A will be neglible for agricultural watersheds, except in cases of extensive outcrops along channel reaches.

EPXM: This interception storage parameter is a function of cover density.

| | |
|---|---|
| Grassland | 0.10 in. |
| Forest cover (light) | 0.15 in. |
| Forest cover (heavy) | 0.20 inc. |

UZSN: The nominal storage in the upper zone is related to LZSN and watershed topography.

| | |
|---|---|
| Low depression storage, steep slopes, limited vegetation | 0.06xLZSN |
| Moderate depression storage slopes and vegetation | 0.08xLZSN |
| High depression storage, soil fissures, flat slopes, heavy vegetation | 0.14xLZSN |

LZSN: The nominal lower zone soil moisture storage parameter is related to the annual cycle of rainfall and evapotranspiration. Approximate values range from 5.0 to 20.0 inches for most of the continental U.S. depending on soil properties. The proper value will need to be checked by computer trials.

K3: Index to actual evaporation. Values range from 0.25 for open land and grassland to 0.7-0.9 for heavy forest. The area covered by forest or deep rooted vegetation as a fraction of total watershed area is an estimate of K3.

K24L,
K24EL: These parameters control the loss of water from near surface or active groundwater storage to deep percolation and transpiration respectively. K24L is the fraction of the groundwater recharge that percolates to deep groundwater table. Thus a value of 1.0 for K24L would preclude any groundwater contribution to surface runoff. K24EL is the fraction of watershed area where shallow water tables put groundwater within reach of vegetation.

INFILTRATION: This parameter is also a function of soil characteristics. As for LZSN, approximate or initial values will need to be checked by computer trails. INFILATRATION can range from 0.01 to 1.0 in/hr depending on the cohesiveness and permeability of the soil.

INTERFLOW: This parameter alters runoff timing, and is closely related to INFILTRATION and LZSN. Examples of its effect are discussed below.

L: Length of overland flow is obtained from topographic maps and approximates the length of travel to a stream channel. Its value can be approximated by dividing the watershed area by twice the length of the stream channel.

SS: Average overland flow slope is also obtained from topographic maps. The average slope can be estimated by superimposing a grid pattern on the watershed, estimating the land slope at each point of the grid, and obtaining the average of all values measured.

NN: Manning's n for overland flow. Approximate values are:

| | |
|---|---|
| Asphalt | 0.014 |
| Packed Clay | 0.03 |
| Turf | 0.25 |
| Heavy Turf and Forest Litter | 0.35 |

IRC; KK24: These parameters are the interflow and groundwater recession rates. They can be estimated graphically[51] or found by trial from simulation runs.

$$\text{IRC} = \frac{\text{Interflow discharge on any day}}{\text{Interflow discharge 24 hours earlier}} \qquad (39)$$

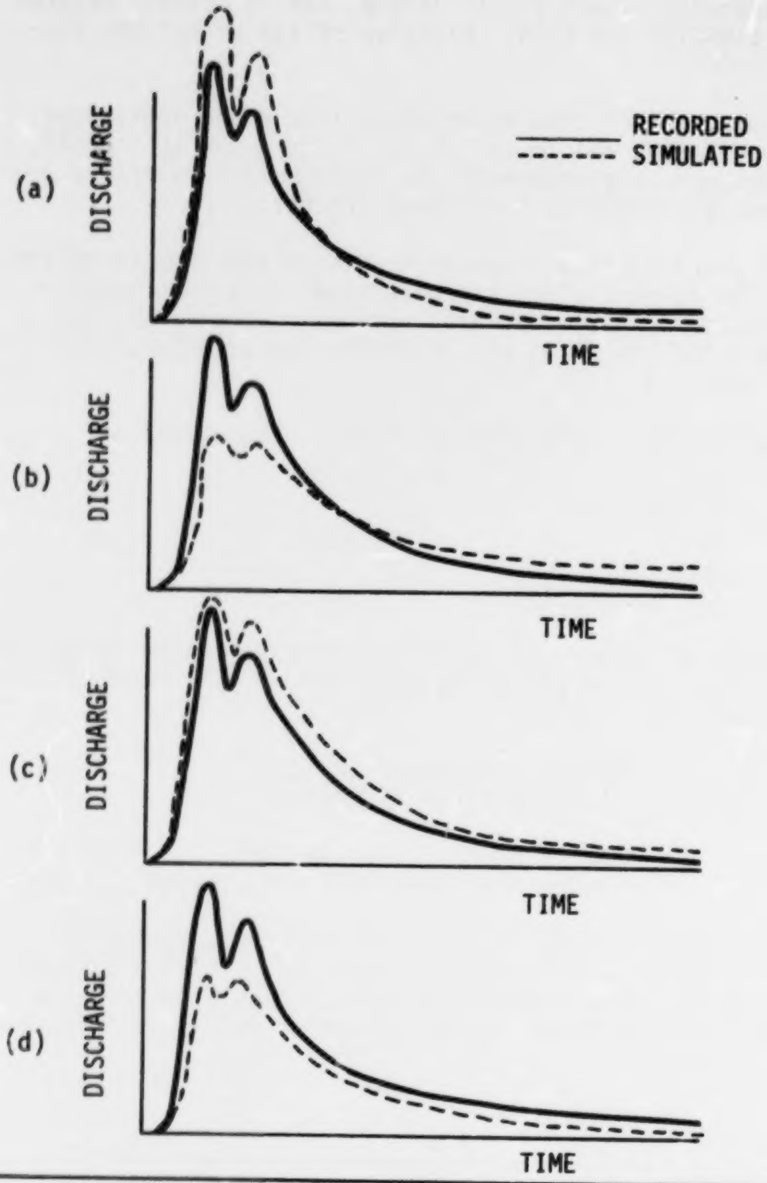
$$\text{KK24} = \frac{\text{Groundwater discharge on any day}}{\text{Groundwater discharge 24 hours earlier}} \qquad (40)$$

KV: The parameter KV (Eqn. 35) is used to allow a variable recession rate for groundwater discharge. If KV = 1.0 the effective recession rate for different levels of KK24 and the variable groundwater slope parameter GWS is as follows:

| | GWS | | | |
|---|---|---|---|---|
| KK24 | 0.0 | 0.5 | 1.0 | 2.0 |
| 0.99 | 0.99 | 0.985 | 0.98 | 0.97 |
| 0.98 | 0.98 | 0.97 | 0.96 | 0.94 |
| 0.97 | 0.97 | 0.955 | 0.94 | 0.91 |
| 0.96 | 0.96 | 0.94 | 0.92 | 0.88 |

## CALIBRATION

Among all of the parameters used in HSP, LZSN, INFILTRATION and INTERFLOW are three that are not clearly defined from physical watershed characteristics. LZSN and INFILTRATION affect both runoff volumes and runoff timing. INTERFLOW effects only runoff timing.



| Indicated Correction in INFILTRATION | (a) | (b) | (c) | (d) |
|---|---|---|---|---|
| from surface runoff volume | increase | decrease | increase | decrease |
| from groundwater flow | increase | decrease | decrease | increase |
| Remarks on results | consistent | | conflicting | |

Figure 43. Examples of hydrograph response with indicated corrections to INFILTRATION parameter

LZSN and INFILTRATION: The nominal lower zone storage and the infiltration index control runoff volumes, if the parameter UZSN is based on LZSN. Runoff volumes over extended periods are governed by the water balance equation:

$$\text{Precipitation} - \text{Actual Evapotranspiration} - \text{Deep percolation} = \text{Streamflow} \qquad (41)$$

Thus when deep percolation is small and precipitation is known, actual evapotranspiration must be changed to cause a change in long-term runoff volume. Increasing LZSN will increase actual evapotranspiration loss, and decreasing LZSN will reduce actual evapotranspiration loss. The parameter INFILTRATION is also directly related to actual evapotranspiration. Lowering INFILTRATION will usually reduce actual evapotranspiration.

When correct annual runoff volumes are obtained, the seasonal distribution of runoff should be checked using the monthly summaries from the LANDS load module. INFILTRATION parameter adjustments are effective in altering groundwater recharge for improved seasonal distribution. When detailed hydrographs from the CHANNEL load module are available the INFILTRATION parameter can be closely checked. Fig. 43 shows the possible results. Cases (a) and (b) indicate that an increase and decrease respectively is in order for the INFILTRATION parameter. Cases (c) and (d) give conflicting indications and unrepresentative input data is likely. These cases should be ignored in the fitting process.

Trial runs are used to determine if cases (a) and (b) predominate during the calibration period and the INFILTRATION parameter is adjusted accordingly. Note that Fig. 43 (a) and (b) illustrate the effect of INFILTRATION on groundwater flows. Groundwater flow is a very useful indicator of infiltration levels.

INTERFLOW: The interflow parameter can be used effectively to alter hydrograph shape after storm runoff volumes have been correctly adjusted. INTERFLOW has no effect on runoff volumes. Its effect is illustrated in Fig. 44 for which values of INTERFLOW were (a) 1.4, (b) 1.8, (c) 1.0.

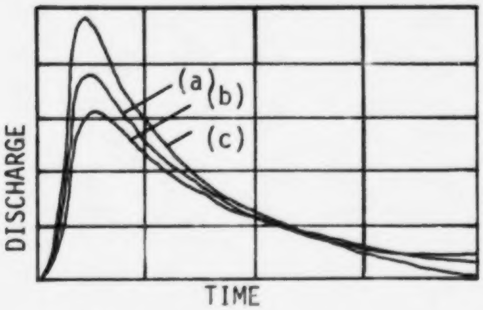


Figure 44. Example of the response to the INTERFLOW parameter

Appendix B

```
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/* SERVICE CLASS=B, BLOCK=W
//JOBLIB DD DSNAME=C510.TONY.PEST10,DISP=(OLD,KEEP),
//       UNIT=2314,VOL=SER=SYS13
//STEP1 EXEC PGM=PEST
//SYSPRINT DD SYSOUT=A
//FT06F001 DD SYSOUT=A
//FT05F001 DD *
 &HYCL  HYCAL= 0,  HYMIN=0.001, UNIT=-1, INPUT=-1 &END
 &PRNT  PRINT= 1 &END
 &STRT  BGNDAY=1, BGNMON=7, BGNYR=1972  &END
 &ENDD  ENDDAY=15,  ENDMON=2, ENDYR=1973 &END
 &TRVL  INTRVL=5  &END
 &LND1  UZSN=0.05, LZSN=18.0, INFIL=0.5, INTER=0.7  &END
 &LND2  IRC=0.0, NN=0.20, L=160., SS=0.05, A=0.00, UZS=0.05 &END
 &LND3  LZS=20.0, SGW=0.0, GWS=0.0, KV=0.0, K24L=1.0, KK24=0.6  &END
 &LND4  ICS=0.0, OFS=0.0, IFS=0.0, K24EL=0.0, K3=0.40, EPXM=0.12  &END
 &PEST  SSTR=5*13.4, APMODE=0, DEPTH=6.125  &END
 &NAME  PNAME='PARAQUAT', WSNAME='P1'  &END
 &CROP  COVMAX=0.60,TIMST=182.,TIMAP=182.,TIMAT=274.,TIMHAR=334. &END
 &SMDL  JRER=3.0, KRER=0.09, JSER=1.0, KSER=1.5, SRERI=9.0 &END
 &AMDL  CMAX=0.00001,DD=0.0003,BULKD=103.0,K=120.,N=2.,AREA=6.7  &END
 &VOL1  DIFC=30.0, TDIFC=30.0, CBDIF=0.11  &END
 &VOL2  MOLEWT=335., APFAC=0.0, BPFAC=0.0, WCFAC=1.0 &END
 &DEG1  DEGCON=0.0001  &END
 EVAP72      27    32    96   154   167   185   245   124   145    93     7    30
 EVAP72      27   176   141    49   175   200   262   194   139   116    52    30
 EVAP72      43   410   148    84   198   162    93   219   138   116    61    30
 EVAP72      41   252   118    91   190   285    93   242   238    67    61    30
 EVAP72      41    44    74   105   198   116   234   200   140    45    61    34
 EVAP72      70    63   192   140   251   239   234    89   169   124   107    19
 EVAP72      43    32   163   140   198   231   141   259    92   142    71    19
 EVAP72     119   139   126   154    91   231   141   280    75   144    81    14
 EVAP72      54    57   155   189   122   216   125   283   203   109    29     5
 EVAP72      54     0   148   161   228   162   177   157   106   172    53     5
 EVAP72      54   132   155    70   220   285   177   112   133    97    53     5
 EVAP72      54    63   141   112   175   185   148   132   114    29    53    10
 EVAP72      54    76   215   126    84   200   171   107   113   112    47    25
 EVAP72      59    69   126   147   243   231   158   129   151    82    97    16
 EVAP72     108   189   126   252   205   216   199   164   149    89    68    21
 EVAP72     124    63    89   175   236   200   206   119   159   146    29    21
 EVAP72     103    76   118   280   152   216    67   115    73   114    78    21
 EVAP72       0   151    67   224   144   185   152   156    61    56    78    31
 EVAP72      49   265    74   210   137   131    92   174   129    52    78    16
 EVAP72      11   277    89   168    84   154   272   150   152   156    53    47
 EVAP72      11    69   141   196   219   154   211   204   108   148    20    16
 EVAP72      11    88   178    42   129   377   195   205   112    66    30    26
 EVAP72      65    31   200   189   106   370   227    59   129    86    30    26
 EVAP72      59    38    74   182   167   223   158   133   108   208    30    78
 EVAP72      97    32   111   238   205   216   141   137    84    17    30    42
```

Appendix  B    (continued)

```
 EVAP72     97    69    96   112   289   277   141   126    48    90    30    16
 EVAP72     22   101    96    98   243   123   111   123   117   186    71    52
 EVAP72      0    76    81   252   106    39   322   156   141    75     4   104
 EVAP72     27   113    89    63    68   246    99   151   104    58    43    36
 EVAP72     27         141   140    53   285   158   187    94    75   102    42
 EVAP72     27          74         122         109   184          58          62
 TEMP72                                       24.4  23.0  22.9  14.5  14.9   2.2
 TEMP72                                       25.6  25.0  22.5  14.2  16.9
 TEMP72                                       24.4  24.3  24.1  16.6  21.4
 TEMP72                                       25.6  26.1  25.0  18.4         8.3
 TEMP72                                       23.9  25.9  20.8  19.7        16.1
 TEMP72                                       21.4  24.9  20.0  17.7  15.2  18.3
 TEMP72                                       20.6  26.7  19.9  18.8  12.8  10.4
 TEMP72                                       22.2  26.5  20.9  16.9   9.3   9.0
 TEMP72                                       22.8  24.7  24.6  17.6   9.2
 TEMP72                                       22.2  24.7  24.4  19.2  12.1
 TEMP72                                       23.9  23.4  19.3  16.1
 TEMP72                                       24.7  25.3  21.1  17.5
 TEMP72                                       27.2  24.4  21.7  21.7  14.0
 TEMP72                                       25.9  24.4  23.4  20.6  15.6
 TEMP72                                       27.4  25.8  25.2  21.7   9.9
 TEMP72                                       26.1  26.7  24.7  19.4   7.7
 TEMP72                                       25.9  24.9  24.9  22.2   5.9
 TEMP72                                       26.0  27.4  23.3  18.8   7.5
 TEMP72                                       26.3  27.3  25.5  16.6   8.6
 TEMP72                                       25.3  27.7  26.1  11.3   6.2
 TEMP72                                       26.3  24.9  22.3   6.9   7.8
 TEMP72                                       28.9  23.6  23.9  13.8   7.8
 TEMP72                                       28.3  22.7  24.2  17.4   5.3
 TEMP72                                       28.9  24.4  23.3  20.9   3.3
 TEMP72                                       26.6  25.2  23.3  13.8   8.3
 TEMP72                                       26.3  24.6  23.3  14.8   7.5
 TEMP72                                       25.4  24.8  25.3  14.8   6.1
 TEMP72                                       25.4  24.4  24.6  13.6  10.6
 TEMP72                                       25.1  25.4  26.3  16.6   8.8
 TEMP72                                       23.2  23.8  20.8  15.4   6.3
 TEMP72                                       21.6  22.7        16.4
 WIND72                                         66    28    25    41    14    31
 WIND72                                         70    79    24    48    79    32
 WIND72                                         68    46    21    45    57    32
 WIND72                                         72    58    40    44    58    37
 WIND72                                         69    59    47    16    58    48
 WIND72                                         67    31    32    60    88    88
 WIND72                                         64    75     9    72    70    78
 WIND72                                         67    71    26    48    83    44
 WIND72                                         64    71    42    47    16    44
 WIND72                                         67    40    48    78    46    45
 WIND72                                         64    35    24    25    46    88
...
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```

Appendix B (continued)

```
WIND72      67    15    12    29    47    17
WIND72      70    26    13    28    83    73
WIND72      30    18    43    33    93    69
WIND72       0    20    17    25    63
WIND72      75    39    27    46    33
WIND72      33    49    22    48    57
WIND72      30    26    22    39    58
WIND72      35    21    19    99    58
WIND72      31    39    53    73    68
WIND72      36    34    20    39    17
WIND72      30    28    10    46    56
WIND72      50    27    37    40    56
WIND72      66    18    30    60    56
WIND72      66    15    35    27    56
WIND72      78    19    22    78    57
WIND72     110    20    18    73    90
WIND72     106    26    32    16    65
WIND72     106    24    50   103    80
WIND72      53    44    61    38    68
WIND72      39    52          31
7207019000000000000000000000000000000000000000000000000000000000000000000000000
7207029000000000000000000000000000000000000000000000000000000000000000000000000
7207031000000000000000000000000000000000000000000000000000000000000000000000000
7207032000000000000000000000000000000000000000000000000000000000000000000000000
7207033000000000000000000000000000000000000000000000000000000000000000000000000
7207034000000000000000000000000000000000000000000000000000000000000000000000000
7207035000000000000000000000000000000000000000000000000000000000000000000000000
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7207044000000000000000000000000000000000000000000000000000000000000000000000000
7207045000000000000000000000000000000000000000000000000000000000000000000000000
7207046000000000000000000000000000000000000000000000000000000000000000000000000
7207047000000000000000000000000000000000000000000000000000000000000000000000000
7207048000000000000000000000000000000000000000000000000001010000001000100010000
7207051000010050801010000000000010000000000000000000000000000000000000000000000
7207052000000000000000000000000000000000000000000000000000000000000000000000000
7207053000000000000000000000000000000000000000000000000000000000000000000000000
7207054000000000000000000000000000000000000000000000000000000000000000000000000
7207055000000000000000000000000000000000000000000000000000000000000000000000000
7207056000000000000000000000000000000000000000000000000000000000000000000000000
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7207058000000000000000000000000000000000000000000000000000000000000000000000000
7207069000000000000000000000000000000000000000000000000000000000000000000000000
7207079000000000000000000000000000000000000000000000000000000000000000000000000
7207089000000000000000000000000000000000000000000000000000000000000000000000000
7207099000000000000000000000000000000000000000000000000000000000000000000000000
720710900000000000000000000000000000000000000 000000000000000000000000000000000
7207119000000000000000000000000000000000000000000000000000000000000000000000000
```

Appendix B (continued)

```
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72071390000000000000000000000000000000000000000000000000000000000000000000000000
72071490000000000000000000000000000000000000000000000000000000000000000000000000
72071590000000000000000000000000000000000000000000000000000000000000000000000000
72071690000000000000000000000000000000000000000000000000000000000000000000000000
72071790000000000000000000000000000000000000000000000000000000000000000000000000
72071890000000000000000000000000000000000000000000000000000000000000000000000000
72071990000000000000000000000000000000000000000000000000000000000000000000000000
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72072390000000000000000000000000000000000000000000000000000000000000000000000000
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72072590000000000000000000000000000000000000000000000000000000000000000000000000
72072690000000000000000000000000000000000000000000000000000000000000000000000000
72072790000000000000000000000000000000000000000000000000000000000000000000000000
72072810000000000000000000000000000000000000000000000000000000000000000000000000
72072820000000000000000000000000000000000000000000000000000000000000000000000000
72072830000000000000000000000000000000000000000000000000000000000000000000000000
72072840000000000000000000000000000000000000000000000000000000000000000000000000
72072850000000000000000000000000000000000000000000000000000000000000000000000000
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72072870100000000000000000000000000000000000000000000000082121200200020001000000
72072880000000000000000000000000000000000000000000000000000000000000000000000000
72072990000000000000000000000000000000000000000000000000000000000000000000000000
72073090000000000000000000000000000000000000000000000000000000000000000000000000
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72073120000000000000000000000000000000000000000000000000000000000000000000000000
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72080290000000000000000000000000000000000000000000000000000000000000000000000000
72080390000000000000000000000000000000000000000000000000000000000000000000000000
72080490000000000000000000000000000000000000000000000000000000000000000000000000
72080590000000000000000000000000000000000000000000000000000000000000000000000000
72080690000000000000000000000000000000000000000000000000000000000000000000000000
72080790000000000000000000000000000000000000000000000000000000000000000000000000
72080890000000000000000000000000000000000000000000000000000000000000000000000000
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Appendix B (continued)

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72080910000000000000000000000000000000000000000000000000000000000000000000000000
72080920000000000000000000000000000000000000000000000000000000000000000000000000
72080930000000000000000000000000000000000000000000000000000000000000000000000000
72080940000000000000000000000000000000000000000000000000000000000000000000000000
72080950000000000000000000000000000000000000000000000000000000000000000000000000
72080960000000000000000000000000000000000000000000000000000000000000000000000000
72080970000000000000000000000000000000000000000000000000000000000000000000000000
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72081010000000000000000000000000000000000000000000000000000000000000000000000000
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72081030000000000000000000000000000000000000000000000000000000000000000000000000
72081040000000000000000000000000000000000000000000000000000000000000000000000000
72081050000000000000000000000000000000000000000000000000000000000000000000000000
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72081070000000000000000000000000000000000000000000000000000503010000000012162417
72081081509000000000000000000000000000000000000000000000000000000000000000000000
72081110000000000000000000000000000000000000000000000000000000000000000000000000
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72081160000000000000000000000000000000000000000000000000000000000000000000000000
72081170000000000000000000000000000000000000000000000000000000000000000000000000
72081180000000000000000000000000000000000000000000000000000000000000000000000000
72081290000000000000000000000000000000000000000000000000000000000000000000000000
72081390000000000000000000000000000000000000000000000000000000000000000000000000
72081490000000000000000000000000000000000000000000000000000000000000000000000000
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72082380000000000000000000000000000000000000000000000000000000000000000000000000
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72082590000000000000000000000000000000000000000000000000000000000000000000000000
72082690000000000000000000000000000000000000000000000000000000000000000000000000
72082710000000000000000000000000000000000000000000000000000000000000000000000000
72082720000000000000000000000000000000000000000000000000000000000000000000000000
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Appendix B (continued)

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7208275000000000000000000000000000000000000000000000000000000000000000000000000
7208276000000000000000000000000000000000000000050507070000000000000000000000000
7208277000000000000000000000000000000000000000000000000000000000000000000000000
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7209039000000000000000000000000000000000000000000000000000000000000000000000000
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7209042000000000000000000000000000000000000000000000000000000000000000000000000
7209043000000000000000000000000000000000000000000000000000000000000000000000000
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7209045000000000000000000000000000000000000000000000000000000000000000000000000
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7209047000101030101010001030100000000000100000000000000000000000000000000000000
7209048000000000000000000000000000000000000000000000000000000000000000000000000
7209051000000000000000000000000000000000000000000000000000000000000000000000000
7209052000000000000000000000000000000000000000000000000000000000000000000000000
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7209054000000000000000000000000000000000000000000000000101020101020201000000000
7209055000000000000000000000000000000000000000000000000000000000101010100000000
7209056000000000000000000000000000000000000000000000000000000000000000000000000
7209057000000000000000000000000000000000000000000000000000000000000000000000000
7209058000000000000000000000000000000000000000000000000000000000000000000000000
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7209079000000000000000000000000000000000000000000000000000000000000000000000000
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7209119000000000000000000000000000000000000000000000000000000000000000000000000
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7209159000000000000000000000000000000000000000000000000000000000000000000000000
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7209172000000000000000000000000000000000000000000000000000000000000000000000000
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7209175000000000000000000000000000000000000000000000000000000000000000000000000
7209176000000000000000000000000000000000000000000000000000000000000000000000000
7209177000000000000000000000000000000000000000000000000000000000000000000000000
7209178000000000000000000000000000000000000000000000000000000000000000000000000
```

Appendix B (continued)

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7209181000000000000000000000000000000000000000000000000000000000000000000000000
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7209183050302000000000000000000000000000000000000000000000000000000000000000000
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7209185000000000000000000000000000000000000000000000000000000000000000000000000
7209186000000000000000000000000000000000000000000000000000000000000000000000000
7209187000000000000000000000000000000000000000000000000000000000000000000000000
7209188000000000000000000000000000000000000000000000000000000000000000000000000
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7209239000000000000000000000000000000000000000000000000000000000000000000000000
7209249000000000000000000000000000000000000000000000000000000000000000000000000
7209259000000000000000000000000000000000000000000000000000000000000000000000000
7209269000000000000000000000000000000000000000000000000000000000000000000000000
7209279000000000000000000000000000000000000000000000000000000000000000000000000
7209289000000000000000000000000000000000000000000000000000000000000000000000000
7209299000000000000000000000000000000000000000000000000000000000000000000000000
7209301000000000000000000000000000000000000000000000000000000000000000000000000
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7209303000100010204000000000000010103010000000000000000000000000000000000000000
7209304000000000000000000000000000000000000000000000000000000000000000000000000
7209305000000000000000000000000000000000000000000000000000000000000000000000000
7209306000000000000000000000000000000000000000000000000000000000000000000000000
7209307000000000000000000000000000000000000000000000000000000000000000000000000
7209308000000000000000000000000000000000000000000000000000000000000000000000000
7210019
7210029
7210039
7210049
7210051
7210052                           2 1
7210053             1 1       1 2 1               1   1 4         1 1 3 3 2 2 1
7210054
7210055
7210056
7210057
7210058
7210069
7210079
7210089
7210099
7210109
7210119
7210129
7210131
7210132
```

Appendix B (continued)

```
7210133
7210134                                                                   7
7210135
7210136
7210137
7210138
7210149
7210159
7210169
7210179
7210189
7210199
7210209
7210219
7210229
7210231
7210232
7210233
7210234
7210235
7210236
7210237                                5
7210238         1 2 4 3 1       1 3 1                     4         1 1   1 1
7210249
7210259
7210269
7210271
7210272
7210273
7210274                     1 1 2 3 1 1 2 2 3 2 116 1     3 1 4 1
7210275 1           1           1     1 1 1 2       1 7 814 4 3 4 2       1 4 1
7210276 1 1 5 5 1 41  2         1 1 3 5 4 4 3 2 1     1 3 2 2 1
7210277
7210278
7210281 2                     2                                             2 2
7210282
7210283
7210284
7210285
7210286
7210287
7210288
7210299
7210309
7210319
7211019
7211029
7211031
```

Appendix B (continued)

```
7211032                                                               1 4
7211033     1 2 4
7211034
7211035
7211036
7211037
7211038
7211049
7211059
7211069
7211071
7211072
7211073                                 1 1 1
7211074   2 1   1 3 1       2 3 6                         1 2
7211075   2         1 2 1     1 1 1       2
7211076                           2 4 8 1               1 2 1 1 3 4 4 3 3 1 1 1
7211077 2 2 4 6 3 2
7211078
7211089
7211099
7211109
7211119
7211129
7211131
7211132
7211133
7211134
7211135
7211136
7211137
721113800001705180000010102000000010104000000000301010101000000000000000000000
7211149
7211159
7211169
7211179
7211189
7211191                                                               100000000
7211192                                                   1
7211193                                 102               1           101020000
72111940001                       1               201         101     101010001
7211195                                           10100020004040001010204020603
72111960300020404000100010201010402010101                   403020301       101
72111970101
7211198
7211209
7211219
7211229
7211239
```

Appendix B (continued)

```
7211249
7211251
7211252
7211253                     101030101010201010101010101010202010101000000010101
72112540101       1010102       202010101010101010101010101       1           1
7211255020100050501000101010102020                          204
7211256
7211257
7211258
7211269
7211279
7211289
7211299
7211301
7211302
7211303                       50101       10101030302
7211304
7211305
7211306
7211307
7211308
7212019
7212029
7212039
7212049
7212051
7212052
7212053
7212054
7212055
7212056
7212057                                   202010000030204010303030101   1010101
7212058                                       2 2 2 2 2 1   1 1 2 1 1 1 1 1 1 1
7212061 1 1 1 1 1 3 1 1           2 2 2 2                             2 2
7212062 1
7212063                                                               2 1 1 1
7212064 1 1                                                     1 1 1 1
7212065
7212066
7212067
7212068
7212079
7212081
7212082
7212083
7212084                                       5 2 1
7212085
7212086
```

Appendix  B   (continued)

```
7212087
7212088
7212099
7212109
7212119
7212129
7212139
7212141
7212142
7212143
7212144       2 3 2     1 1   1 1 1
7212145     1 1 1                           1 2 1 1
7212146                                               2 2 2 2 2 2 2 1   2 2 4 7
7212147 7 2 2 2 2 2 2 2 2 3 410 31212 8 9 9 1 5 1   2   2   1 1     1 1 1 1   4
7212148 1 2 2 7 8 2 7 9 2 1101010 8 2 3 2 3 2 3 2 3 2 3 7 3 1 1 1 2 1 1
7212151 1 1 1       1 1   1 1 1 2 315 3 1 1 4 2 3 2 4 1 1 2 3 3 4 1 1 1 1 1 1 5
7212152 1 2 8 5 1   1 2 1       1 1 1 1     1     2   1   1           1 1 1 1 1
7212153                                                             3 3 3 4   2
7212154 2 2 210 5 3 2 1 1 1 1 1 2   1 1
7212155
7212156
7212157
7212158
7212169
7212179
7212189
7212199
7212201
7212202
7212203
7212204
7212205
7212206
7212207
7212208                                                         7 3 1 4 1 1 1
7212211 4 2 3 5 1 1 1 5 2 8 1 1 1 3 1     4 4 3 2 4 1 5 1 8 1 6 6 1 1 1
7212212     1 1 1 1 1                   1 1                       1 1 1
7212213 1 2 1 1   1 1   1   1   1   1     1   1   1   1   1 1 1 1 1 1 1 1     3
7212214 1 1 1     1 1 2 3 3 1 3 3 1 1 1 2 1 1 2 3 5 2 1 3 2 2 1 1 1 1
7212215                                                     3 3 3
7212216
7212217 1 1 1 1 1         1 1 1 1 1                 2 4
7212218       1 1 1 1                                   1 1 1 1 1   1 1 1 1 1
7212221                         1   1   1   1   1   1   1   1   1   1
7212222
7212223
7212224
7212225
```

Appendix B (continued)

```
7212226
7212227
7212228
7212239
7212249
7212259
7212269
7212279
7212289
7212299
7212309
7212311
7212312
7212313 2 1 1 1 1 1 2 1 4 2 1   2 1 2 1 1 1   1 1 1     3 2 2 3 2 3 1 1 2 1 2 1
7212314                                                 1 1 1 1
7212315                                         2
7212316   1 1 1               1 1 1 1 1     1 1 1 1 1           1 1 1 1 1
7212317
7212318
EVAP73    108    50
EVAP73     54    31
EVAP73     43   132
EVAP73     49    31
EVAP73     76    82
EVAP73     27    19
EVAP73     27    63
EVAP73     27    44
EVAP73      0    88
EVAP73     54    63
EVAP73     27    50
EVAP73     27    44
EVAP73     32    31
EVAP73     43    19
EVAP73     43    69
EVAP73     38   120
EVAP73     22    76
EVAP73     38    25
EVAP73     54    57
EVAP73     86    57
EVAP73     76   101
EVAP73     81   145
EVAP73     97   132
EVAP73     86   101
EVAP73     43    82
EVAP73     70    25
EVAP73     43    82
EVAP73     59    88
           65
```

Appendix  B   (continued)

```
              53
               0
TEMP72                        24.4  23.0  22.9  14.5  14.9   2.2
TEMP72                        25.6  25.0  22.5  14.2  16.9
TEMP72                        24.4  24.3  24.1  16.6  21.4
TEMP72                        25.6  26.1  25.0  18.4         8.3
TEMP72                        23.9  25.9  20.8  19.7        16.1
TEMP72                        21.4  24.9  20.0  17.7  15.2  18.3
TEMP72                        20.6  26.7  19.9  18.8  12.8  10.4
TEMP72                        22.2  26.5  20.9  16.9   9.3   9.0
TEMP72                        22.8  24.7  24.6  17.6   9.2
TEMP72                        22.2  24.7  24.4  19.2  12.1
TEMP72                        23.9  23.4  19.3  16.1
TEMP72                        24.7  25.3  21.1  17.5
TEMP72                        27.2  24.4  21.7  21.7  14.0
TEMP72                        25.9  24.4  23.4  20.6  15.6
TEMP72                        27.4  25.8  25.2  21.7   9.9
TEMP72                        26.1  26.7  24.7  19.4   7.7
TEMP72                        25.9  24.9  24.9  22.2   5.9
TEMP72                        26.0  27.4  23.3  18.8   7.5
TEMP72                        26.3  27.3  25.5  16.6   8.6
TEMP72                        25.3  27.7  26.1  11.3   6.2
TEMP72                        26.3  24.9  22.3   6.9   7.8
TEMP72                        28.9  23.6  23.9  13.8   7.8
TEMP72                        28.3  22.7  24.2  17.4   5.3
TEMP72                        28.9  24.4  23.3  20.9   3.3
TEMP72                        26.6  25.2  23.3  13.8   8.3
TEMP72                        26.3  24.6  23.3  14.8   7.5
TEMP72                        25.4  24.8  25.3  14.8   6.1
TEMP72                        25.4  24.4  24.6  13.6  10.6
TEMP72                        25.1  25.4  26.3  16.6   8.8
TEMP72                        23.2  23.8  20.8  15.4   6.3
TEMP72                        21.6  22.7        16.4
WIND72                          66    28    25    41    14    31
WIND72                          70    79    24    48    79    32
WIND72                          68    46    21    45    57    32
WIND72                          72    58    40    44    58    37
WIND72                          69    59    47    16    58    48
WIND72                          67    31    32    60    88    88
WIND72                          64    75     9    72    70    78
WIND72                          67    71    26    48    83    44
WIND72                          64    71    42    47    16    44
WIND72                          67    40    48    78    46    45
WIND72                          64    35    24    25    46    88
WIND72                          67    15    12    29    47    17
WIND72                          70    26    13    28    83    73
WIND72                          30    18    43    33    93    69
WIND72                           0    20    17    25    63
```

Appendix B (continued)

```
 WIND72
 WIND72                                         75    39    27    46    33
 WIND72                                         33    49    22    48    57
 WIND72                                         30    26    22    39    58
 WIND72                                         35    21    19    99    58
 WIND72                                         31    39    53    73    68
 WIND72                                         36    34    20    39    17
 WIND72                                         30    28    10    46    56
 WIND72                                         50    27    37    40    56
 WIND72                                         66    18    30    60    56
 WIND72                                         66    15    35    27    56
 WIND72                                         78    19    22    78    57
 WIND72                                        110    20    18    73    90
 WIND72                                        106    26    32    16    65
 WIND72                                        106    24    50   103    80
 WIND72                                         53    44    61    38    68
7301019                                         39    52          31
7301029
7301031
7301032
7301033                                                         1 1     1 1 1
7301034 1   1   1   1   1   2   1   2         1 1 1 1 1         2 1 1 1
7301035             1 1                                 1 1   1
7301036
7301037                                                     3   1   1
7301038
7301041             1 1                 1 1 1
7301042
7301043
7301044
7301045
7301046
7301047
7301048
7301051
7301052
7301053
7301054
7301055
7301056
7301057                 7 3 1   2 2
7301058         1 1 1 1 1         1 1 1 1 1               1 1 1 1 1
7301061   1 1 1 1 1 1 1 1 1 1   3 1 1 1 1 1 2 2 3
7301062 1   1   1   1   1                                       3 2 1 1 1 1 1
7301063
7301064
7301065
7301066
```

Appendix B (continued)

```
7301067
7301068
7301071
7301072
7301073
7301074
7301075                         1 1 1 1 1   1   1 1 1 1   1   1   1   1   1
7301076             1           1 1 1 1 1 1     1 1 1
7301077 1 1 1 1 1 1 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 1 1 2 1 2 1 1 1 1
7301078 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2
7301081 1 1 1 2 1 2 1 2 1 2 1 2 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1
7301082                         1 1 1 1 1 1 1 1 1 1 1 1
7301083
7301084
7301085
7301086
7301087
7301088
7301099
7301109
7301119
7301129
7301139
7301149
7301159
7301169
7301179
7301189
7301191
7301192             5 3   1 1   1 1 1 1 2 2 2 2 1 1 1 3 1 1 4 1 4 1 2 1
7301193
7301194
7301195
7301196
7301197
7301198
7301209
7301219
7301229
7301239
7301249
7301251
7301252
7301253
7301254
7301255
7301256
7301257
```

Appendix B (continued)

```
7301258     4                                             1   1   1 1 1 1 1 1 1
7301261 1 1 3 3 4 2 2 1 1 1 1   1   1 1   1 1   1 1       1 1 1 1 1 2 3 2 4 2 2
7301262 4 2 2 1 1 2 2 2 2 2                       4 1 1   1   1   1   1
7301263
7301264
7301265
7301266
7301267
7301268
7301279
7301281
7301282
7301283
7301284
7301285
7301286
7301287           1 1 1                                 1 1
7301288   1 1 1
7301299
7301309
7301319
7302019
7302029
7302039
7302049
7302059
7302061
7302062
7302063
7302064                                             3 2 1 1
7302065
7302066
7302067
7302068
7302079
7302081
7302082
7302083                 1 1 1               1 1
7302084                                                 1 1
7302085                                     1 1 1 1 1 3 3 2 1 1 1 1 1
7302086
7302087
7302088
7302099
7302101
7302102
7302103
7302104
```

Appendix B (continued)

```
 7302105
 7302106
 7302107
 7302108
 7302119
 7302129
 7302139
 7302149
 7302151
 7302152
 7302153 1 2 1 1 2 1 1 1 2 1 1 1 2 1 1 1 1 1   1   1   1 2 3 2 1 1 1 1 1 1 1 1
 7302154
 7302155
 7302156
 7302157
 7302158
/*
```

## Appendix C PTR MODEL LISTING

```
//PESTICID JOB (C510,510,3,8),'TONY.PEST10.COMPILED'
/* SERVICE CLASS=B, BLOCK=NIGHT
//STEP1 EXEC FORTHCL,PARM.FORT='OPT=2,MAP,XREF'
//FORT.SYSIN DD *
C
C
C
C
C                           PESTICIDE MODEL -- MAIN PROGRAM
C
      IMPLICIT  REAL(L)
C
      DIMENSION  RXB(5), RGX(5), RUZB(5), UZSB(5), PERCB(5), RIB(5)
      DIMENSION  ROBTOM(5), ROBTOT(5), INFTOM(5), INFTOT(5), INTF(5)
      DIMENSION  ROITOM(5), ROITOT(5), ERSTOM(5), ERSTOT(5)
      DIMENSION  PRSTOM(5), PRSTOT(5), PROTOM(5), PROTOT(5)
      DIMENSION  UPITOM(5), UPITOT(5), RESB1(5), SSTR(5), USTR(5)
      DIMENSION  ERSN(5), SRER(5), SRGX(5), RESB(5), IEVAP(12,31)
      DIMENSION  SAS(5), SCS(5), SDS(5), SPRP(5), STS(5)
      DIMENSION  UAS(5), UCS(5), UDS(5), UPRP(5), UPRI(5), UTS(5)
      DIMENSION  UZSBMT(5), RESBMT(5), SRGXMT(5), SRERMT(5)
      DIMENSION  STSMET(5), SASMET(5), SCSMET(5), SDSMET(5)
      DIMENSION  UTSMET(5), UASMET(5), UCSMET(5), UDSMET(5)
      DIMENSION  ERSNMT(5)
      DIMENSION  RAIN(288), IRAIN(288), MNAM(24), ROSB(5)
      DIMENSION  PRTTOT(5), PRTTOM(5), IWIND(12,31), ITEMP(12,31)
C
      COMMON  PRTOT, ERSNTT, EIMTT, PRTT, IHR
      COMMON  PRTOM, ERSNTM, EIMTM, PRTM, IMIN
      COMMON  RUTOM, NEPTOM, ROSTOM, RITOM, RINTOM, BASTOM, RCHTOM
      COMMON  RUTOT, NEPTOT, ROSTOT, RITOT, RINTOT, BASTOT, RCHTOT
      COMMON  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT
      COMMON  PRSTOM, PRSTOT, PROTOM, PROTOT, UPITOM, UPITOT
      COMMON  RESB, RESB1, ROSB, TWBAL, SRGX, RU, HYMIN, INTF
      COMMON  MNAM, IX, IZ, DAY, IFLAG, COVER, COVMAX
      COMMON  SPROTM, SPRSTM, ERSTOM, ERSTOT, EPTOM, EPTOT, PRNTKE
      COMMON  STS, STST, SAST, SCST, SDST, UTS, UTST, UAST, UCST, UDST
      COMMON  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, HYCAL, DPST, RIB,UNIT
      COMMON  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS, SGW1
      COMMON  A, UZS, LZS, SGW, GWS, KV, K24L, KK24, K24EL, TF, EP
      COMMON  IFS, K3, EPXM, RESS1, RESS, SCEP, SCEP1, SRGXT, SRGXT1
      COMMON  SRER, JRER, KRER, JSER, KSER, ERSN, SRERT
      COMMON  SAS, SCS, SDS, AREA, M, K, FP, CMAX, SSTR, NI, BULKD
      COMMON  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT
      COMMON  UAS, UCS, UDS, USTR, MUZ, FPUZ
      COMMON  UPRP, UPRITM, UPRITT, MMPIN, METOPT, KGPLB
      COMMON  FPLZ, MLZ, LSTR, LAS, LCS, LDS, LPRP
      COMMON  GSTR, GAS, GCS, GDS
      COMMON  APMODE, CADIF, CBDIF, TEMP, WIND, CONCIU
      COMMON  MOLEWT, APFAC, BPFAC, WCFAC
      COMMON  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS
      COMMON  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS, DEGCON
      COMMON  DEGLOM, DEGLOT
```

```
C
      INTEGER  BGNDAY, BGNMON, BGNYR, ENDDAY, ENDMON, ENDYR
      INTEGER  DYSTRT, DYEND, YEAR, MONTH, DAY, H, HYCAL, TIME
      INTEGER  YR, MO, DY, CN, TF, PRNTKE, PRINT, DA, APMODE, UNIT
      INTEGER  INPUT
C
      REAL  IRC, NN, KV, K24L, KK24, INFIL, INTER
      REAL  IFS, ICS, K24EL, K3, NEPTOM, NEPTOT
      REAL  JRER, KRER, JSER, KSER
      REAL  M, MM, N, NI, K, MUZ, MU, ML, MLZ
      REAL  INFTOM, INFTOT, MOLEWT, ITEMP
      REAL  MMPIN, METOPT, KGPLB, QMETRC
      REAL  UZSMET, LZSMET, SGWMET, SCEPMT, RESSMT, TWBLMT
      REAL  SRGXTM, SRRTMT, SASTMT, SCSTMT, SDSTMT, STSTMT
      REAL  UTSTMT, UASTMT, UCSTMT, UDSTMT, LSTRMT, LASMET
      REAL  LCSMET, LDSMET, GSTRMT, GASMET, GCSMET, GDSMET
      REAL  VLTMMT, TPBALM, ERSNTT, EIMMET, ERSNMT
      REAL*8  PNAME, WSNAME
C
      DATA  PRINT/1/
      DATA  COUNT, TIMAT, TIMST, TIMAP/4*0.0/
      DATA  ICS, OFS, TPBAL, DEGT/4*0.0/
      DATA  PRTTOM, PRTTOT, PRT, VOLT, TOTPAP/13*0.0/
C
C
C                  DATA INPUT -- SINGLE-VALUED VARIABLES
C
      NAMELIST /HYCL/  HYCAL, HYMIN, UNIT, INPUT
      NAMELIST /PRNT/  PRINT
      NAMELIST /STRT/  BGNDAY, BGNMON, BGNYR
      NAMELIST /ENDD/  ENDDAY, ENDMON, ENDYR
      NAMELIST /TRVL/  INTRVL
      NAMELIST /LND1/  UZSN, LZSN, INFIL, INTER
      NAMELIST /LND2/  IRC, NN, L, SS, A, UZS
      NAMELIST /LND3/  LZS, SGW, GWS, KV, K24L, KK24
      NAMELIST /LND4/  ICS, OFS, IFS, K24EL, K3, EPXM
      NAMELIST /PEST/  SSTR, APMODE, DEPTH
      NAMELIST /NAME/  PNAME, WSNAME
      NAMELIST /CROP/  COVMAX, TIMST, TIMAP, TIMAT, TIMHAR
      NAMELIST /SMDL/  JRER, KRER, JSER, KSER, SRERI
      NAMELIST /AMDL/  CMAX, DD, BULKD, K, N, AREA
      NAMELIST /VOL1/  DIFC, TDIFC, CBDIF
      NAMELIST /VOL2/  MOLEWT, APFAC, BPFAC, WCFAC
      NAMELIST /DEG1/  DEGCON
C
C        INPUT PARAMETER DESCRIPTION
C  HYCAL : INDICATES WHAT FACTORS ARE TO BE SIMULATED
C        = -1  CALIBRATION RUN WITH PESTICIDE
```

```
C        =  0  PRODUCTION RUN
C        =  1  CALIBRATION RUN, NO PESTICIDES
C  HYMIN : MINIMUM FLOW FOR OUTPUT DURING A TIME INTERVAL (CFS, CMS)
C  INPUT : INPUT UNITS; ENGLISH(-1), METRIC(1)
C  UNIT  : OUTPUT UNITS; ENGLISH(-1), METRIC(1), BOTH(0)
C  PRINT : DENOTES FREQUENCY OF OUTPUT; EACH INTERVAL(-1),
C          EACH HOUR(0), OR EACH DAY(1)
C  BGNDAY, BGNMON, BGNYR : DATE SIMULATION BEGINS
C  ENDDAY, ENDMON, ENDYR : DATE SIMULATION ENDS
C  INTRVL: TIME INTERVAL ( 5 OR 15 MINUTES)
C  UZSN  : NOMIMAL UPPER ZONE STORAGE (IN, MM)
C  LZSN  : NOMINAL LOWER ZONE STORAGE (IN, MM)
C  INFIL : INFILTRATION RATE (IN/HR, MM/HR)
C  INTER : INTERFLOW PARAMETER, ALTERS RUNOFF TIMING
C  IRC   : INTERFLOW RECESSION RATE
C  NN    : MANNING'S N FOR OVERLAND FLOW
C  L     : LENGTH OF OVERLAND FLOW TO CHANNEL (FT, M)
C  SS    : AVERAGE OVERLAND FLOW SLOPE
C  A     : FRACTION OF AREA THAT IS IMPERVIOUS
C  UZS   : INITIAL UPPER ZONE STORAGE (IN, MM)
C  LZS   : INITIAL LOWER ZONE STORAGE (IN, MM)
C  SGW   : INITIAL GROUNDWATER STORAGE (IN, MM)
C  GWS   : GROUNDWATER SLOPE
C  KV    : PARAMETER TO ALLOW VARIABLE RECESSION RATE FOR GROUNDWATER
C          DISCHARGE
C  K24L  : FRACTION OF GROUNDWATER RECHARGE PERCOLATING TO DEEP
C          GROUNDWATER
C  KK24  : GROUNDWATER RECESSION RATE
C  ICS   : INITIAL INTERCEPTION STORAGE (IN, MM)
C  OFS   : INITIAL OVERLAND FLOW STORAGE (IN, MM)
C  IFS   : INITIAL INTERFLOW STORAGE (IN, MM)
C  K24EL : FRACTION OF WATERSHED AREA WHERE GROUNDWATER IS WITHIN
C          REACH OF VEGETATION
C  K3    : INDEX TO ACTUAL EVAPORATION
C  EPXM  : MAXIMUM INTERCEPTION STORAGE (IN, MM)
C  PNAME : PESTICIDE NAME (8 CHARACTERS)
C  WSNAME: WATERSHED NAME (8 CHARACTERS)
C  SSTR  : PESTICIDE APPLICATION FOR EACH ZONE (LB, KG)
C  APMODE: APPLICATION MODE; SURFACE APPLIED(0), SOIL INCORPORATED(1)
C  DEPTH : DEPTH OF SOIL INCORPORATION (IN, MM)
C  COVMAX: MAXIMUM SURFACE AREA COVERED BY VEGETATION
C  TIMST : TIME SIMULATION STARTS (JULIAN DAY)
C  TIMAP : TIME OF PESTICIDE APPLICATION (JULIAN DAY)
C  TIMAT : TIME OF CROP MATURITY (JULIAN DAY)
C  TIMHAR: TIME OF HARVEST (JULIAN DAY)
C  JRER  : EXPONENT OF RAINFALL INTENSITY  IN SOIL SPLASH EQUATION
C  KRER  : COEFFICIENT IN SOIL SPLASH EQUATION
C  JSER  : EXPONENT OF OVERLAND FLOW IN SURFACE SCOUR EQUATION
```

Appendix C (continued)

```
C  KSER  : COEFFICIENT IN SURFACE SCOUR EQUATION
C  SRERI : INITIAL FINES DEPOSIT (TONS, TONNES)
C  CMAX  : MAXIMUM SOLUIBILITY OF PESTICIDE IN WATER (LB/LB)
C  DD    : PERMANENTLY FIXED CAPACITY (LB PESTICIDE/LB SOIL)
C  BULKD : BULK DENSITY OF PESTICIDE (G/CM(3))
C  K     : COEFICIENT IN FREUNDLICH ADSORPTION CURVE
C  N     : EXPONENT IN FREUNLICK ADSORPTION CURVE
C  AREA  : WATERSHED AREA (AC, HA)
C  DIFC  : PESTICIDE DIFFUSION COEFFICIENT (MM(2)/WK)
C  TDIFC : TEMPERATURE AT WHICH DIFC WAS MEASURED (DEGREES CELCIUS)
C  CBDIFC: COEFICIENT FOR DIFFUSION
C  MOLEWT: MOLECULAR WEIGHT OF PESTICIDE (G/MOLE)
C  APFAC, BPFAC : CONSTANTS FOR PRESSURE AND TEMPERATURE ADJUSTMENT
C  WCFAC : WIND CALIBRATION FACTOR
C  DEGCON: FIRST ORDER PESTICIDE DECAY RATE (PER DAY)
C
      READ (5,HYCL)
      READ (5,PRNT)
      READ (5,STRT)
      READ (5,ENDD)
      READ (5,TRVL)
      READ (5,LND1)
      READ (5,LND2)
      READ (5,LND3)
      READ (5,LND4)
      READ (5,PEST)
      READ (5,NAME)
      READ (5,CROP)
      READ (5,SMDL)
      READ (5,AMDL)
      READ (5,VOL1)
      READ (5,VOL2)
      READ (5,DEG1)
C
C                    PRINTING OF INPUT PARAMETERS
C
      IF (HYCAL)  1002, 1001, 1002
C
 1001    WRITE (6,1091)
         WRITE (6,1092)
         GO TO 1003
C
 1002    WRITE (6,1093)
         WRITE (6,1092)
C
C
 1003 WRITE (6,1107) WSNAME
      WRITE (6,1106) PNAME
      IF (INPUT .EQ. -1)  WRITE (6,1108)
      IF (INPUT .EQ.  1)  WRITE (6,1109)
      IF (APMODE .EQ. 1)  WRITE (6,1105)
      IF (APMODE .EQ. 0)  WRITE (6,1104)
      WRITE (6,1092)
C
      WRITE (6,STRT)
      WRITE (6,1092)
      WRITE (6,ENDD)
      WRITE (6,1092)
      WRITE (6,TRVL)
      WRITE (6,1092)
      WRITE (6,LND1)
      WRITE (6,1092)
      WRITE (6,LND2)
      WRITE (6,1092)
      WRITE (6,LND3)
      WRITE (6,1092)
      WRITE (6,LND4)
      WRITE (6,1092)
      WRITE (6,PEST)
      WRITE (6,1092)
      WRITE (6,CROP)
      WRITE (6,1092)
      WRITE (6,SMDL)
      WRITE (6,1092)
      WRITE (6,AMDL)
      WRITE (6,1092)
      WRITE (6,VOL1)
      WRITE (6,1092)
      WRITE (6,VOL2)
      WRITE (6,1092)
      WRITE (6,DEG1)
      WRITE (6,1092)
      WRITE (6,HYCL)
      WRITE (6,1092)
      WRITE (6,PRNT)
      WRITE (6,1092)
      IF (INPUT .EQ. -1) GO TO 950
C
C  CONVERSION OF METRIC INPUT DATA TO ENGLISH UNITS
C
      HYMIN= HYMIN*35.3
      UZSN = UZSN/MMPIN
      LZSN = LZSN/MMPIN
      INFIL= INFIL/MMPIN
      L    = L*3.281
      UZS  = UZS/MMPIN
      LZS  = LZS/MMPIN
      SGW  = SGW/MMPIN
      ICS  = ICS/MMPIN
      OFS  = OFS/MMPIN
      IFS  = IFS/MMPIN
      EPXM = EPXM/MMPIN
      DEPTH= DEPTH/MMPIN
      SRERI= SRERI/METOPT
      AREA = AREA*2.471
      DO 501 I=1,5
  501    SSTR(I)=SSTR(I)/0.4536
C
C                    ADJUSTMENT OF CONSTANTS
C
  950 H = 60/INTRVL
      TIMFAC = INTRVL
      INTRVL = 24*H
C
      KRER = KRER*H**(JRER-1.)
      KSER = KSER*H**(JSER-1.)
      NI = 1./N
C
      MM = BULKD/96.
      MU = BULKD*((DEPTH - 0.125)/12.)
      ML = BULKD*6.
      M = MM*43560.*AREA*0.2
      MUZ = MU*43560.*AREA*0.2
      MLZ = ML*43560.*AREA
C
      DO 1000  I= 1,5
 1000 TOTPAP = TOTPAP + SSTR(I)
C
      IFLAG=1
      COUNT = 0.
      IF  (APMODE .EQ. 0)  GO TO 1004
      CONCIU = (TOTPAP*6./((MUZ + M)*5.))*1000000.*(BULKD/62.43)
C
      DO  999  I= 1,5
      USTR(I) = SSTR(I)
      SSTR(I) = SSTR(I)*(0.125/DEPTH)
  999 USTR(I) = USTR(I) - SSTR(I)
      CADIF = DIFC/(EXP(CBDIF*TDIFC))
C
 1004 FP = DD*M
      FPUZ = DD*MUZ
      FPLZ = DD*MLZ
```

```
C
      DO 1005  I=1,5
         SRER(I) = SRERI*0.2
         UZSB(I) = UZS
         RESB(I) = OFS
         SRGX(I) = IFS
 1005    CONTINUE
C
      RESS1 = OFS
      RESS = OFS
      SCEP = ICS
      SCEP1 = ICS
      SRGXT = IFS
      SRGXT1 = IFS
      SGW1 = SGW
C
C                                PROGRAM EXECUTION
C
      DO 1070  YEAR=BGNYR,ENDYR
         IF (YEAR .EQ. BGNYR) GO TO 998
         TIMST = 0.0
         TIMAP = 0.0
         TIMAT = TIMAT - 365.
         IF (TIMAT .LE. 0.0) TIMAT = 0.0
         TIMHAR = TIMHAR - 365.
         IF (TIMHAR .LE. 0.0) TIMHAR = 0.0
  998    COUNT = TIMST
         COVER = 0.0
         MNSTRT = 1
         MNEND = 12
         IF (YEAR .EQ. BGNYR)  MNSTRT = BGNMON
         IF (YEAR .EQ. ENDYR)  MNEND = ENDMON
C
C
C  EVAPORATION, TEMP, AND WIND  DATA INPUT
C
      DO 1007  NO = 1,31
       DO 1006  MK = 1,12
       IEVAP(MK,NO) = 0
       ITEMP(MK,NO) = 0.0
 1006  IWIND(MK,NO) = 0
 1007 CONTINUE
C
C
      DO  1008  DA = 1,31
 1008  READ (5,1264) (IEVAP(MN,DA), MN =1,12)
C
```

```
C
        DO  1013 DA = 1,31
 1013   READ(5,1265) (ITEMP(MN,DA), MN=1,12)
C
        DO  1014 DA = 1,31
 1014   READ(5,1264) (IWIND(MN,DA), MN=1,12)
        IF (INPUT .EQ. -1) GO TO 625
        DO 700 DA=1,31
           DO 650 MN=1,12
              IEVAP(MN,DA) = IEVAP(MN,DA)*3.937
              IWIND(MN,DA) = IWIND(MN,DA)*0.6214
  650         CONTINUE
  700      CONTINUE
C
C
  625 IF (INPUT .EQ. 1) GO TO 628
      DO 627 DA=1,31
         DO 626 MN=1,12
            ITEMP(MN,DA) = (ITEMP(MN,DA) - 32.)*.5556
  626       CONTINUE
  627     CONTINUE
  628    DO 1060  MONTH=MNSTRT,MNEND
            IF (HYCAL .EQ. 0)  GO TO 1009
            WRITE (6,1263)
            WRITE (6,382)
            WRITE (6,1092)
 1009       DYSTRT = 1
            IF (MOD(YEAR,4))  1012, 1010, 1012
 1010          GO TO (31,29,31,30,31,30,31,31,30,31,30,31), MONTH
 1012          GO TO (31,28,31,30,31,30,31,31,30,31,30,31), MONTH
   28             DYEND = 28
                  GO TO 1015
   29             DYEND = 29
                  GO TO 1015
   30             DYEND = 30
                  GO TO 1015
   31             DYEND = 31
C
 1015       IF (YEAR .NE. BGNYR)  GO TO 1017
            IF (MONTH .NE. BGNMON)  GO TO 1017
            DYSTRT = BGNDAY
C
 1017       IF (YEAR .NE. ENDYR)  GO TO 1018
            IF (MONTH .NE. ENDMON)  GO TO 1018
            DYEND = ENDDAY
C
 1018       DO 1050  DAY=DYSTRT,DYEND
               IF ((MONTH .EQ. 1) .AND. (DAY .EQ. 1)) COUNT = 1.
```

```
                  TIME = 0
                  RAINT = 0.0
                  EP = IEVAP(MONTH,DAY)/1000.
                  TEMP = ITEMP(MONTH,DAY)
                  WIND = IWIND(MONTH,DAY)
 1016             DO 1019  I=1,INTRVL
                     IRAIN(I) = 0
                     RAIN(I) = 0.0
 1019                CONTINUE
C
C        CROP CANOPY EFFECTS - ASSUMES LINEAR GROWTH TO MAX. % COVER
C
                  COUNT = COUNT + 1.
                  IF (COUNT - TIMAP) 1047, 1047, 1046
 1046             IF (COUNT .LT. TIMAT)  GO TO 1045
                  COVER = COVMAX
                  IF (COUNT .GE. TIMHAR)  COVER=0.0
                  GO TO 1047
 1045               COVER = COVMAX*((COUNT-TIMAP)/(TIMAT-TIMAP))
C
C
 1047             IF (INTRVL .EQ. 288)  GO TO 1021
                  DO 1020  J=1,8
                     JK = J*12
                     JJ = JK - 11
                     READ (5,1094)  YR, MO, DY, CN, (IRAIN(I), I=JJ,JK)
                     IF (INPUT .EQ. -1) GO TO 704
                     DO 702 I=JJ,JK
                        IRAIN(I) = IRAIN(I)*3.937 + 0.5
 702                    CONTINUE
 704                 IF (CN .EQ. 9)  GO TO 1025
                     YR = YR + 1900
                     IT = (YEAR-YR) + (MONTH-MO) + (DAY-DY) + (J-CN)
                     IF (IT .EQ. 0)  GO TO 1020
                     WRITE (6,1090)  J, MONTH, DAY, YEAR, CN, MO, DY, YR
                     GO TO 1080
 1020                CONTINUE
                  GO TO 1023
C
 1021             DO 1022  J=1,8
                     JK = J*36
                     JJ = JK - 35
                     READ (5,1095)  YR, MO, DY, CN, (IRAIN(I), I=JJ,JK)
                     IF (INPUT .EQ. -1) GO TO 708
                     DO 706 I=JJ,JK
                        IRAIN(I) =IRAIN(I)*3.937 + 0.5
 706                    CONTINUE
 708                 IF (CN .EQ. 9)  GO TO 1025
```

```
                  YR = YR + 1900
                  IT = (YEAR-YR) + (MONTH-MO) + (DAY-DY) + (J-CN)
                  IF (IT .EQ. 0)  GO TO 1022
                  WRITE (6,1090)  J, MONTH, DAY, YEAR, CN, MO, DY, YR
                  GO TO 1080
 1022             CONTINUE
C
 1023          DO 1024  I=1,INTRVL
                  RAIN(I) = IRAIN(I)/100.
                  RAINT = RAINT + RAIN(I)
 1024             CONTINUE
C
               IF (RAINT)  1025, 1025, 1026
C
C
C  USE RAIN LOOP IF MOISTURE STORAGES ARE NOT EMPTY
C
 1025  IF ((RESS .GE. 0.001).OR.(SRGXT .GE. 0.001)) GO TO 1026
       GO TO 1040
C
C
C                  RAIN LOOP
C
 1026          DO 1036  I=1,INTRVL
                  TIME = TIME + 1
                  TF = 1
                  PR = RAIN(I)
C
                  IMIN = MOD(TIME,H)
                  IHR = (TIME - IMIN)/H
                  IMIN = TIMFAC*IMIN
                  PRNTKE = 0
                  IF (PRINT)  1027, 1028, 1029
 1027                PRNTKE = 1
                     GO TO 1030
 1028                IF (IMIN .LT. 1)  PRNTKE = 1
                     GO TO 1030
 1029                IF (IHR .EQ. 24)  PRNTKE = 1
C
 1030             IF (PRNTKE .EQ. 0)  GO TO 1031
                  IX = 2*MONTH
                  IZ = IX - 1
C
                  IF (HYCAL .NE. 0)  GO TO 1031
C
 1037             WRITE (6,1101)  IHR, IMIN, DAY,MNAM(IZ),MNAM(IX),YEAR
                  WRITE (6,1102)
                  WRITE (6,1103)
```

```
C
 1031             CALL LANDS
                  IF ((RESS .GE. 0.001).OR.(PR .GT. 0.001))  GO TO 1034
                  DO 1033  J=1,5
                     ERSN(J) = 0.0
 1033                CONTINUE
                  IF (PRNTKE .EQ. 0)  GO TO 1035
 1034             CALL SEDT
 1035       IF ((HYCAL .EQ. 1) .OR. (COUNT .LT. TIMAP))  GO TO 1036
                  CALL ADSRB1
                  CALL ADSRB2
                  CALL ADSRB3
                  IF (IHR .EQ. 24)  GO TO 1038
                   VOLU = 0.0
                   VOLS = 0.0
                   DEGS = 0.0
                   DEGU = 0.0
                   GO TO 1036
 1038             CALL VOLDEG
 1036             CONTINUE
C
              GO TO 1050
C
C                  NO RAIN LOOP
C
C
 1040         TF = INTRVL
              PR = 0.0
              P3 = 0.0
              DO  1042  I=1,5
 1042            RESB1(I) = 0.0
              PRNTKE = 1
              IMIN = 00
              IHR = 24
              IX = 2*MONTH
              IZ = IX - 1
              IF (HYCAL .NE. 0)  GO TO 1043
              WRITE (6,1101)  IHR, IMIN, DAY, MNAM(IZ), MNAM(IX), YEAR
              WRITE (6,1102)
              WRITE (6,1103)
C
 1043         CALL LANDS
              SRERT = 0.0
              ERSNT = 0.0
              EIM = 0.0
              DO 1041  J=1,5
                 SRERT = SRERT + SRER(J)
                 ERSN(J) = 0.0
 1041             CONTINUE
               IF (HYCAL .NE. 0)  GO TO 1044
             IF (UNIT .EQ. 1) GO TO 1081
               WRITE (6,1209)
               WRITE (6,1210) ERSN, ERSNT
               WRITE (6,1211)  SRER, SRERT
               WRITE (6,1212) EIM
 1081          IF (UNIT .EQ. -1) GO TO 1044
C  METRIC CONVERSIONS FOR OUTPUT
               ERSNTT=ERSNT*METOPT
               SRRTMT=SRERT*METOPT
               EIMMET=EIM*METOPT
               DO 1163 I=1,5
                 ERSNMT(I)=ERSN(I)*METOPT
                 SRERMT(I)=SRER(I)*METOPT
 1163          CONTINUE
               WRITE (5,1208)
               WRITE (6,1210) ERSNMT, ERSNTT
               WRITE (6,1211) SRERMT, SRRTMT
               WRITE (6,1212) EIMMET
 1044       IF ((HYCAL .EQ. 1) .OR. (COUNT .LT. TIMAP))  GO TO 1050
               CALL ADSRB1
               CALL ADSRB2
               CALL ADSRB3
               CALL VOLDEG
C
 1050          CONTINUE
C
C                   MONTHLY SUMMARY
C
          DO 1051  I= 1,5
 1051     PRTTOM(I) = PRSTOM(I) + PROTOM(I) + UPITOM(I)
C
C
          VOLTOM = VOLSOM + VOLUOM
          VOLT = VOLT + VOLTOM
          DEGTOM = DEGSOM + DEGUOM + DEGLOM
          DEGT = DEGT + DEGTOM
C
            PRTM = SPROTM + SPRSTM + UPRITM
          PRT = PRT + PRTM
C
          PBAL = STST + UTST + LSTR + GSTR + PRT
     X           + VOLT + DEGT - TOTPAP
          IF ((PBAL .LE. 0.0).AND.(PBAL .GE. -0.0009))  PBAL = 0.0
          TPBAL = TPBAL + PBAL
C
            IX = 2*MONTH
            IZ = IX - 1
            WRITE (6,1200)  MNAM(IZ), MNAM(IX), YEAR
            WRITE (6,1201)
            WRITE (6,1103)
C
      IF (UNIT .EQ. 1) GO TO 1053
      WRITE (6,360)
      WRITE (6,361) PRTOM,PRTOM,PRTOM,PRTOM,PRTOM,PRTOM
      WRITE (6,362)
      WRITE (6,363) ROBTOM, ROSTOM
      WRITE (6,364) INFTOM, RINTOM
      WRITE (6,365) RITOM
      WRITE (6,366) ROITOM, RUTOM
      WRITE (6,380) BASTOM
      WRITE (6,381) RCHTOM
      WRITE (6,367)
      WRITE (6,368) EPTOM,EPTOM,EPTOM,EPTOM,EPTOM,EPTOM
      WRITE (6,369) NEPTOM,NEPTOM,NEPTOM,NEPTOM,NEPTOM,NEPTOM
      WRITE (6,370)
      WRITE (6,371) UZSB,UZS
      WRITE (6,372) LZS,LZS,LZS,LZS,LZS,LZS
      WRITE (6,373) SGW,SGW,SGW,SGW,SGW,SGW
      WRITE (6,374) SCEP,SCEP,SCEP,SCEP,SCEP,SCEP
      WRITE (6,375) RESB,RESS
      WRITE (6,376) SRGX,SRGXT
      WRITE (6,377) TWBAL
            WRITE (6,1209)
            WRITE (6,1210) ERSTOM,  ERSNTM
            WRITE (6,1211)  SRER, SRERT
            WRITE (6,1212)  EIMTM
            IF (HYCAL .NE. 0)  GO TO 1052
            WRITE (6,1220)
            WRITE (6,1221)  STS, STST
            WRITE (6,1222)  SAS, SAST
            WRITE (6,1223)  SCS, SCST
            WRITE (6,1227) SDS, SDST
            WRITE (6,1224)  UTS, UTST
            WRITE (6,1222)  UAS, UAST
            WRITE (6,1223)  UCS, UCST
            WRITE (6,1227)  UDS, UDST
            WRITE (6,1228)  LSTR
            WRITE (6,1229)  LAS
            WRITE (6,1230)  LCS
            WRITE (6,1231)  LDS
            WRITE (6,1232)  GSTR
            WRITE (6,1229)  GAS
            WRITE (6,1230)  GCS
            WRITE (6,1231)  GDS
```

```
 1052       WRITE (6,1240)  PRTTOM, PRTM
            WRITE (6,1241)  PROTOM, SPROTM
            WRITE (6,1242)  PRSTOM, SPRSTM
            WRITE (6,1243)  UPITOM, UPRITM
          IF (HYCAL .EQ. 1)  GO TO 1053
            WRITE (6,1244)
            WRITE (6,1245) VOLTOM
            WRITE (6,1246) VOLSOM
            WRITE (6,1247) VOLUOM
            WRITE (6,1248)
            WRITE (6,1245) DEGTOM
            WRITE (6,1246) DEGSOM
            WRITE (6,1247) DEGUOM
            WRITE (6,1252) DEGLOM
            WRITE (6,1266) TPBAL
C
 1053 IF (UNIT .EQ. -1) GO TO 1055
C  CONVERSIONS TO METRIC
C  NEW PARAMETERS DEFINED FOR VARIABLES NOT RESET TO ZERO.
C
      PRTOM =PRTOM*MMPIN
      ROSTOM=ROSTOM*MMPIN
      RINTOM=RINTOM*MMPIN
      RITOM =RITOM*MMPIN
      RUTOM =RUTOM*MMPIN
      BASTOM =BASTOM*MMPIN
      RCHTOM=RCHTOM*MMPIN
      EPTOM =EPTOM*MMPIN
      NEPTOM =NEPTOM*MMPIN
      UZSMET=UZS*MMPIN
      LZSMET=LZS*MMPIN
      SGWMET=SGW*MMPIN
      SCEPMT=SCEP*MMPIN
      RESSMT=RESS*MMPIN
      TWBLMT=TWBAL*MMPIN
      SRGXTM=SRGXT*MMPIN
C  SEDIMENT
      ERSNTM=ERSNTM*METOPT
      SRRTMT=SRERT*METOPT
      EIMTM=EIMTM*METOPT
C  PESTICIDE
      STSTMT=STST*KGPLB
      SASTMT=SAST*KGPLB
      SCSTMT=SCST*KGPLB
      SDSTMT=SDST*KGPLB
      UTSTMT=UTST*KGPLB
      UASTMT=UAST*KGPLB
      UCSTMT=UCST*KGPLB
      UDSTMT=UDST*KGPLB
      LSTRMT=LSTR*KGPLB
      LASMET=LAS*KGPLB
      LCSMET=LCS*KGPLB
      LDSMET=LDS*KGPLB
      GSTRMT=GSTR*KGPLB
      GASMET=GAS*KGPLB
      GCSMET=GDS*KGPLB
      GDSMET=GDS*KGPLB
      PRTM  =PRTM*KGPLB
      SPROTM=SPROTM*KGPLB
      SPRSTM=SPRSTM*KGPLB
      UPRITM=UPRITM*KGPLB
      VLTMMT=VOLTOM*KGPLB
      VOLSOM=VOLSOM*KGPLB
      VOLUOM=VOLUOM*KGPLB
      DEGTMT=DEGTOM*KGPLB
      DEGSMT=DEGSOM*KGPLB
      DEGUMT=DEGUOM*KGPLB
      DEGLMT=DEGLOM*KGPLB
      TPBALM=TPBAL*KGPLB
C
C ARRAY METRIC MODIFICATIONS
      DO 1048 I=1,5
        ROBTOM(I)=ROBTOM(I)*MMPIN
        INFTOM(I)=INFTOM(I)*MMPIN
        ROITOM(I)=ROITOM(I)*MMPIN
        UZSBMT(I)=UZSB(I)*MMPIN
        RESBMT(I)=RESB(I)*MMPIN
        SRGXMT(I)=SRGX(I)*MMPIN
        ERSTOM(I)=ERSTOM(I)*METOPT
        SRERMT(I)=SRER(I)*METOPT
        STSMET(I)=STS(I)*KGPLB
        SASMET(I)=SAS(I)*KGPLB
        SCSMET(I)=SCS(I)*KGPLB
        SDSMET(I)=SDS(I)*KGPLB
        UTSMET(I)=UTS(I)*KGPLB
        UASMET(I)=UAS(I)*KGPLB
        UCSMET(I)=UCS(I)*KGPLB
        UDSMET(I)=UDS(I)*KGPLB
        PRTTOM(I)=PRTTOM(I)*KGPLB
        PROTOM(I)=PROTOM(I)*KGPLB
        PRSTOM(I)=PRSTOM(I)*KGPLB
        UPITOM(I)=UPITOM(I)*KGPLB
 1048 CONTINUE
      WRITE (6,460)
      WRITE (6,461) PRTOM,PRTOM,PRTOM,PRTOM,PRTOM,PRTOM
      WRITE (6,362)
      WRITE (6,463) ROBTOM,ROSTOM
      WRITE (6,464) INFTOM,RINTOM
      WRITE (6,465) RITOM
      WRITE (6,466) ROITOM,RUTOM
      WRITE (6,480) BASTOM
      WRITE (6,481) RCHTOM
      WRITE (6,367)
      WRITE (6,468) EPTOM,EPTOM,EPTOM,EPTOM,EPTOM,EPTOM
      WRITE (6,469) NEPTOM,NEPTOM,NEPTOM,NEPTOM,NEPTOM,NEPTOM
      WRITE (6,370)
      WRITE (6,471) UZSBMT,UZSMET
      WRITE (6,472) LZSMET,LZSMET,LZSMET,LZSMET,LZSMET,LZSMET
      WRITE (6,473) SGWMET,SGWMET,SGWMET,SGWMET,SGWMET,SGWMET
      WRITE (6,474) SCEPMT,SCEPMT,SCEPMT,SCEPMT,SCEPMT,SCEPMT
      WRITE (6,475) RESBMT,RESSMT
      WRITE (6,476) SRGXMT,SRGXTM
      WRITE (6,477) TWBLMT
      WRITE (6,1208)
      WRITE (6,1210) ERSTOM,ERSNTM
      WRITE (6,1211) SRERMT,SRRTMT
      WRITE (6,1212) EIMTM
        IF (HYCAL .NE. 0) GO TO 1049
      WRITE (6,1207)
      WRITE (6,1221) STSMET,STSTMT
      WRITE (6,1222) SASMET,SASTMT
      WRITE (6,1223) SCSMET,SCSTMT
      WRITE (6,1227) SDSMET,SDSTMT
      WRITE (6,1224) UTSMET,UTSTMT
      WRITE (6,1222) UASMET,UASTMT
      WRITE (6,1223) UCSMET,UCSTMT
      WRITE (6,1227) UDSMET,UDSTMT
      WRITE (6,1228) LSTRMT
      WRITE (6,1229) LASMET
      WRITE (6,1230) LCSMET
      WRITE (6,1231) LDSMET
      WRITE (6,1231) GSTRMT
      WRITE (6,1229) GASMET
      WRITE (6,1230) GCSMET
      WRITE (6,1231) GDSMET
 1049 WRITE (6,1239) PRTTOM,PRTM
      WRITE (6,1241) PROTOM,SPROTM
      WRITE (6,1242) PRSTOM,SPRSTM
      WRITE (6,1243) UPITOM,UPRITM
        IF (HYCAL .EQ. 1) GO TO 1055
      WRITE (6,1238)
      WRITE (6,1245) VLTMMT
      WRITE (6,1246) VOLSOM
      WRITE (6,1247) VOLUOM
      WRITE (6,1249)
      WRITE (6,1245) DEGTMT
      WRITE (6,1246) DEGSMT
      WRITE (6,1247) DEGUMT
      WRITE (6,1252) DEGLMT
      WRITE (6,1266) TPBALM
C                   ZEROING OF VARIABLES
C
 1055      PRTOM = 0.0
      RUTOM = 0.0
      NEPTOM = 0.0
      ROSTOM = 0.0
      RITOM = 0.0
      RINTOM = 0.0
      BASTOM = 0.0
      RCHTOM = 0.0
            EPTOM = 0.0
            ERSNTM = 0.0
            EIMTM = 0.0
            PRTM = 0.0
            SPROTM = 0.0
            SPRSTM = 0.0
            UPRITM = 0.0
            VOLSOM = 0.0
            VOLUOM = 0.0
            DEGSOM = 0.0
            DEGUOM = 0.0
            DEGLOM = 0.0
C
            DO 1058  I=1,5
               ERSTOM(I) = 0.0
               ROBTOM(I) = 0.0
               INFTOM(I) = 0.0
               PRTTOM(I) = 0.0
               PROTOM(I) = 0.0
               PRSTOM(I) = 0.0
               UPITOM(I) = 0.0
 1058          ROITOM(I)= 0.0
C
 1060       CONTINUE
C
C                   YEARLY SUMMARY
            DO 1061  I= 1,5
 1061       PRTTOT(I) = PRSTOT(I) + PROTOT(I) + UPITOT(I)
C
            VOLTOT = VOLSOT + VOLUOT
            DEGTOT = DEGSOT + DEGUOT + DEGLOT
```

```
C
            PRTT = SPROTT + SPRSTT + UPRITT
C
C
         WRITE (6,1250)  YEAR
         WRITE (6,1251)
         WRITE (6,1103)
C
      IF (UNIT .EQ. 1) GO TO 1066
      WRITE (6,360)
      WRITE (6,361) PRTOT,PRTOT,PRTOT,PRTOT,PRTOT,PRTOT
      WRITE (6,362)
      WRITE (6,363) ROBTOT, ROSTOT
      WRITE (6,364) INFTOT, RINTOT
      WRITE (6,365) RITOT
      WRITE (6,366) ROITOT, RUTOT
      WRITE (6,380) BASTOT
      WRITE (6,381) RCHTOT
      WRITE (6,367)
      WRITE (6,368) EPTOT,EPTOT,EPTOT,EPTOT,EPTOT,EPTOT
      WRITE (6,369) NEPTOT,NEPTOT,NEPTOT,NEPTOT,NEPTOT,NEPTOT
      WRITE (6,370)
      WRITE (6,371) UZSB,UZS
      WRITE (6,372) LZS,LZS,LZS,LZS,LZS,LZS
      WRITE (6,373) SGW,SGW,SGW,SGW,SGW,SGW
      WRITE (6,374) SCEP,SCEP,SCEP,SCEP,SCEP,SCEP
      WRITE (6,375) RESB,RESS
      WRITE (6,376) SRGX,SRGXT
      WRITE (6,377) TWBAL
         WRITE (6,1209)
         WRITE (6,1210) ERSTOT,  ERSNTT
         WRITE (6,1211)  SRER, SRERT
         WRITE (6,1212)  EIMTT
            IF (HYCAL .NE. 0)  GO TO 1063
         WRITE (6,1220)
         WRITE (6,1221)  STS, STST
         WRITE (6,1222)  SAS, SAST
         WRITE (6,1223)  SCS, SCST
         WRITE (6,1227) SDS, SDST
         WRITE (6,1224)  UTS, UTST
         WRITE (6,1222)  UAS, UAST
         WRITE (6,1223)  UCS, UCST
         WRITE (6,1227)  UDS, UDST
         WRITE (6,1228)  LSTR
         WRITE (6,1229)  LAS
         WRITE (6,1230)  LCS
         WRITE (6,1231)  LDS
         WRITE (6,1232)  GSTR
         WRITE (6,1229)  GAS
         WRITE (6,1230)  GCS
         WRITE (6,1231)  GDS
 1063    WRITE (6,1240)  PRTTOT, PRTT
         WRITE (6,1241)  PROTOT, SPROTT
         WRITE (6,1242)  PRSTOT, SPRSTT
         WRITE (6,1243)  UPITOT, UPRITT
          IF (HYCAL .EQ. 1)  GO TO 1066
         WRITE (6,1244)
         WRITE (6,1245)  VOLTOT
         WRITE (6,1246)  VOLSOT
         WRITE (6,1247)  VOLUOT
         WRITE (6,1248)
         WRITE (6,1245) DEGTOT
         WRITE (6,1246) DEGSOT
         WRITE (6,1247) DEGUOT
         WRITE (6,1252) DEGLOT
         WRITE (6,1266) TPBAL
 1066 IF (UNIT .EQ. -1) GO TO 1065
C  CONVERSIONS
      PRTOT =PRTOT*MMPIN
      ROSTOT=ROSTOT*MMPIN
      RINTOT=RINTOT*MMPIN
      RITOT =RITOT*MMPIN
      RUTOT =RUTOT*MMPIN
      BASTOT=BASTOT*MMPIN
      RCHTOT=RCHTOT*MMPIN
      EPTOT =EPTOT*MMPIN
      NEPTOT=NEPTOT*MMPIN
      UZSMET=UZS*MMPIN
      LZSMET=LZS*MMPIN
      SGWMET=SGW*MMPIN
      SCEPMT=SCEP*MMPIN
      RESSMT=RESS*MMPIN
      TWBLMT=TWBAL*MMPIN
      SRGXTM=SRGXT*MMPIN
      ERSNTT=ERSNTT*METOPT
      SRRTMT=SRERT*METOPT
      EIMTT =EIMTT*METOPT
C  PESTICIDE
      STSTMT=STST*KGPLB
      SASTMT=SAST*KGPLB
      SCSTMT=SCST*KGPLB
      SDSTMT=SDST*KGPLB
      UTSTMT=UTST*KGPLB
      UASTMT=UAST*KGPLB
      UCSTMT=UCST*KGPLB
      UDSTMT=UDST*KGPLB
      LSTRMT=LSTR*KGPLB
      LASMET=LAS*KGPLB
      LCSMET=LCS*KGPLB
      LDSMET=LDS*KGPLB
      GSTRMT=GSTR*KGPLB
      GASMET=GAS*KGPLB
      GCSMET=GDS*KGPLB
      GDSMET=GDS*KGPLB
      PRTT  =PRTT*KGPLB
      SPROTT=SPROTT*KGPLB
      SPRSTT=SPRSTT*KGPLB
      UPRITT=UPRITT*KGPLB
      VLTMMT=VOLTOT*KGPLB
      VOLSOT=VOLSOT*KGPLB
      VOLUOT=VOLUOT*KGPLB
      DEGTMT=DEGTOT*KGPLB
      DEGSMT=DEGSOT*KGPLB
      DEGUMT=DEGUOT*KGPLB
      DEGLMT=DEGLOT*KGPLB
      TPBALM=TPBAL*KGPLB
C  METRIC MODIFICATION OF ARRAYS
      DO 1062 I=1,5
        ROBTOT(I)=ROBTOT(I)*MMPIN
        INFTOT(I)=INFTOT(I)*MMPIN
        ROITOT(I)=ROITOT(I)*MMPIN
        UZSBMT(I)=UZSB(I)*MMPIN
        RESBMT(I)=RESB(I)*MMPIN
        SRGXMT(I)=SRGX(I)*MMPIN
        ERSTOT(I)=ERSTOT(I)*METOPT
        SRERMT(I)=SRER(I)*METOPT
        STSMET(I)=STS(I)*KGPLB
        SASMET(I)=SAS(I)*KGPLB
        SCSMET(I)=SCS(I)*KGPLB
        SDSMET(I)=SDS(I)*KGPLB
        UTSMET(I)=UTS(I)*KGPLB
        UASMET(I)=UAS(I)*KGPLB
        UCSMET(I)=UCS(I)*KGPLB
        UDSMET(I)=UDS(I)*KGPLB
        PRTTOT(I)=PRTTOT(I)*KGPLB
        PROTOT(I)=PROTOT(I)*KGPLB
        PRSTOT(I)=PRSTOT(I)*KGPLB
        UPITOT(I)=UPITOT(I)*KGPLB
 1062 CONTINUE
C
      WRITE (6,460)
      WRITE (6,461) PRTOT,PRTOT,PRTOT,PRTOT,PRTOT,PRTOT
      WRITE (6,362)
      WRITE (6,463) ROBTOT,ROSTOT
      WRITE (6,464) INFTOT,RINTOT
      WRITE (6,465) RITOT
      WRITE (6,466) ROITOT,RUTOT
      WRITE (6,480) BASTOT
      WRITE (6,481) RCHTOT
      WRITE (6,367)
      WRITE (6,468) EPTOT,EPTOT,EPTOT,EPTOT,EPTOT,EPTOT
      WRITE (6,469) NEPTOT,NEPTOT,NEPTOT,NEPTOT,NEPTOT,NEPTOT
      WRITE (6,370)
      WRITE (6,471) UZSBMT,UZSMET
      WRITE (6,472) LZSMET,LZSMET,LZSMET,LZSMET,LZSMET,LZSMET
      WRITE (6,473) SGWMET,SGWMET,SGWMET,SGWMET,SGWMET,SGWMET
      WRITE (6,474) SCEPMT,SCEPMT,SCEPMT,SCEPMT,SCEPMT,SCEPMT
      WRITE (6,475) RESBMT,RESSMT
      WRITE (6,476) SRGXMT,SRGXTM
      WRITE (6,477) TWBLMT
      WRITE (6,1208)
      WRITE (6,1210) ERSTOT,ERSNTT
      WRITE (6,1211) SRERMT,SRRTMT
      WRITE (6,1212) EIMTT
        IF (HYCAL .NE. 0) GO TO 1064
      WRITE (6,1207)
      WRITE (6,1221) STSMET,STSTMT
      WRITE (6,1222) SASMET,SASTMT
      WRITE (6,1223) SCSMET,SCSTMT
      WRITE (6,1227) SDSMET,SDSTMT
      WRITE (6,1224) UTSMET,UTSTMT
      WRITE (6,1222) UASMET,UASTMT
      WRITE (6,1223) UCSMET,UCSTMT
      WRITE (6,1227) UDSMET,UDSTMT
      WRITE (6,1228) LSTRMT
      WRITE (6,1229) LASMET
      WRITE (6,1230) LCSMET
      WRITE (6,1231) LDSMET
      WRITE (6,1231) GSTRMT
      WRITE (6,1229) GASMET
      WRITE (6,1230) GCSMET
      WRITE (6,1231) GDSMET
1064  WRITE (6,1239) PRTTOT,PRTT
      WRITE (6,1241) PROTOT,SPROTT
      WRITE (6,1242) PRSTOT,SPRSTT
      WRITE (6,1243) UPITOT,UPRITT
        IF (HYCAL .EQ. 1) GO TO 1065
      WRITE (6,1238)
      WRITE (6,1245) VLTMMT
      WRITE (6,1246) VOLSOT
      WRITE (6,1247) VOLUOT
      WRITE (6,1249)
      WRITE (6,1245) DEGTMT
      WRITE (6,1246) DEGSMT
      WRITE (6,1247) DEGUMT
      WRITE (6,1252) DEGLMT
      WRITE (6,1266) TPBALM
C
C                    ZEROING OF VARIABLES
C
 1065    PRTOT = 0.0
      RUTOT = 0.0
      NEPTOT = 0.0
      ROSTOT = 0.0
      RITOT = 0.0
      RINTOT = 0.0
      BASTOT = 0.0
      RCHTOT = 0.0
         EPTOT = 0.0
         ERSNTT = 0.0
         EIMTT = 0.0
         PRTT = 0.0
         SPROTT = 0.0
         SPRSTT = 0.0
         UPRITT = 0.0
         VOLSOT = 0.0
         VOLUOT = 0.0
         DEGSOT = 0.0
         DEGUOT = 0.0
         DEGLOT = 0.0
C
         DO 1068  I=1,5
            ERSTOT(I) = 0.0
            ROBTOT(I) = 0.0
            INFTOT(I) = 0.0
            PRTTOT(I) = 0.0
            PRSTOT(I) = 0.0
            PROTOT(I) = 0.0
            UPITOT(I) = 0.0
 1068       ROITOT(I) = 0.0
C
 1070    CONTINUE
C
 1080 CONTINUE
      WRITE (6,1260)
C
C                    FORMAT STATEMENTS
C
 1090 FORMAT ('1','*****ERROR*****  INCORRECT INPUT DATA½   DESIRED '
     *   'CARD ',I1,' FOR ',I2,'/',I2,'/',I4,'; READ CARD ',I1,' FOR ',
    *   I2,'/',I2,'/',I4)
 1091 FORMAT ('1',25X,'THIS IS A PRODUCTION RUN')
 1092 FORMAT ('0')
 1093 FORMAT ('1',25X,'THIS IS A CALIBRATION RUN FOR LANDS')
 1094 FORMAT (1X,3I2,I1,12I6)
 1095 FORMAT (1X,3I2,I1,36I2)
 1101 FORMAT ('1',25X,I2,':',I2,'  ON  ',I2,1X,A4,A4,1X,I4)
 1102 FORMAT ('+',25X,'____________________________' )
 1103 FORMAT ('0',35X,'ZONE 1    ZONE 2    ZONE 3    ZONE 4    ZONE 5',
    C  5X,'TOTAL')
 1104 FORMAT ('0',32X,'APPLICATION:  SURFACE-APPLIED')
 1105 FORMAT ('0',32X,'APPLICATION:  SOIL-INCORPORATED')
 1106 FORMAT ('0',32X,'PESTICIDE:    ',A10)
 1107 FORMAT ('0',32X,'WATERSHED:    ',A10)
 1108 FORMAT ('0',32X,'INPUT UNITS:    ENGLISH')
 1109 FORMAT ('0',32X,'INPUT UNITS:    METRIC')
 1200 FORMAT ('1',25X,'SUMMARY FOR MONTH OF ',A4,A4,1X,I4)
 1201 FORMAT ('+',25X,'__________________________________')
 1208 FORMAT ('0',8X,'SEDIMENT,TONNES')
 1207 FORMAT ('0',5X,'PESTICIDE, KILOGRAMS')
 1209 FORMAT ('0', 8X,'SEDIMENT, TONS')
 1210 FORMAT (' ',11X,'TOTAL SEDIMENT LOSS',5(3X,F7.3),4X,F7.3)
 1211 FORMAT (' ',11X,'FINES DEPOSIT',6X,5(3X,F7.3),4X,F7.3)
 1212 FORMAT (' ',11X,'IMPERVIOUS EROSION',55X,F7.3)
 1220 FORMAT ('0',5X,'PESTICIDE, POUNDS')
 1221 FORMAT ('0', 8X,'SURFACE LAYER',10X,5(3X,F7.3),3X,F8.3)
 1222 FORMAT (' ',11X,'ADSORBED',12X,5(3X,F7.3),3X,F8.3)
 1223 FORMAT (' ',11X,'CRYSTALLINE',9X,5(3X,F7.3),3X,F8.3)
 1224 FORMAT ('0', 8X,'UPPER ZONE LAYER',7X,5(3X,F7.3),3X,F8.3)
 1227 FORMAT (' ',11X,'DISSOLVED',11X,5(3X,F7.3),3X,F8.3)
 1228 FORMAT ('0', 8X,'LOWER ZONE LAYER',60X,F8.3)
 1229 FORMAT (' ',11X,'ADSORBED',65X,F8.3)
 1230 FORMAT (' ',11X,'CRYSTALLINE',62X,F8.3)
 1231 FORMAT (' ',11X,'DISSOLVED',64X,F8.3)
 1232 FORMAT ('0', 8X,'GROUNDWATER LAYER',59X,F8.3)
 1239 FORMAT ('0',8X,'PESTICIDE REMOVAL, KGS.',2X,5(F7.3,3X),F8.3)
 1238 FORMAT ('0',8X,'PESTICIDE VOLATILIZATION LOSS, KGS.')
 1240 FORMAT ('0', 8X,'PESTICIDE REMOVAL, LBS.',2X,5(F7.3,3X),F8.3)
 1241 FORMAT (' ',11X,'OVERLAND FLOW REMOVAL',1X,5(F7.3,3X),F8.3)
 1242 FORMAT (' ',11X,'SEDIMENT REMOVAL',6X,5(F7.3,3X),F8.3)
 1243 FORMAT (' ',11X,'INTERFLOW REMOVAL',5X,5(F7.3,3X),F8.3)
 1244 FORMAT ('0',8X,'PESTICIDE VOLATILIZATION LOSS, LBS.')
 1245 FORMAT (' ',11X,'TOTAL',68X,F7.3)
 1246 FORMAT (' ',11X,'FROM SURFACE',61X,F7.3)
 1247 FORMAT (' ',11X,'FROM UPPER ZONE',58X,F7.3)
 1248 FORMAT ('0',8X,'PESTICIDE DEGRADATION LOSS, LBS.')
 1249 FORMAT ('0',8X,'PESTICIDE DEGRADATION LOSS, KGS.')
 1250 FORMAT ('1',25X,'SUMMARY FOR ',I4)
 1251 FORMAT ('+',25X,'_________________')
 1252 FORMAT (' ',11X,'FROM LOWER ZONE',58X,F7.3)
 1260 FORMAT ('1')
 1262 FORMAT (2X,A4,A4,2X,I2,2X,I2,':',I2)
 1263 FORMAT ('1',7X,'DATE',4X,'TIME',6X,'FLOW(CFS - CMS)',6X,
     X        'SEDIMENT(LBS - KG - GM/L)',11X,'PESTICIDE (GM - PPM)')
 1265 FORMAT (8X,12F6.1)
 1264 FORMAT (8X,12I6)
 1266 FORMAT ('0',11X,'PESTICIDE_BALANCE=',F8.4)
  360 FORMAT ('0',8X,'WATER, INCHES')
  361 FORMAT ('0',11X,'PRECIPITATION',6X,5(3X,F7.3),4X,F7.3)
  362 FORMAT ('0',11X,'RUNOFF')
  363 FORMAT (' ',14X,'OVERLAND_FLOW',3X,5(3X,F7.3),4X,F7.3)
  364 FORMAT (' ',14X,'INTERFLOW',7X,5(3X,F7.3),4X,F7.3)
  365 FORMAT (' ',14X,'IMPERVIOUS',55X,5X,F7.3)
  366 FORMAT (' ',14X,'TOTAL',11X,5(3X,F7.3),4X,F7.3)
  367 FORMAT ('0',11X,'EVAPORATION')
  368 FORMAT (' ',14X,'POTENTIAL',7X,5(3X,F7.3),4X,F7.3)
  369 FORMAT (' ',14X,'NET',13X,5(3X,F7.3),4X,F7.3)
  370 FORMAT ('0',11X,'STORAGES')
  371 FORMAT (' ',14X,'UPPER_ZONE',6X,5(3X,F7.3),4X,F7.3)
  372 FORMAT (' ',14X,'LOWER_ZONE',6X,5(3X,F7.3),4X,F7.3)
  373 FORMAT (' ',14X,'GROUNDWATER',5X,5(3X,F7.3),4X,F7.3)
  374 FORMAT (' ',14X,'INTERCEPTION',4X,5(3X,F7.3),4X,F7.3)
  375 FORMAT (' ',14X,'OVERLAND_FLOW',3X,5(3X,F7.3),4X,F7.3)
  376 FORMAT (' ',14X,'INTERFLOW',7X,5(3X,F7.3),4X,F7.3)
  377 FORMAT ('0',11X,'WATER_BALANCE=',F8.4)
  378 FORMAT ('+',25X,F5.1)
  380 FORMAT ('0',11X,'BASE_FLOW',64X,F7.3)
  381 FORMAT (' ',11X,'GRDWATER_RECHARGE',56X,F7.3)
  382 FORMAT (' ',78X,'WATER',13X,'SEDIMENT')
  460 FORMAT ('0',8X,'WATER, MILLIMETERS')
  461 FORMAT ('0',11X,'PRECIPITATION',6X,5(3X,F7.2),4X,F7.2)
  463 FORMAT (' ',14X,'OVERLAND_FLOW',3X,5(3X,F7.2),4X,F7.2)
  464 FORMAT (' ',14X,'INTERFLOW',7X,5(3X,F7.2),4X,F7.2)
  465 FORMAT (' ',14X,'IMPERVIOUS',60X,F7.2)
  466 FORMAT (' ',14X,'TOTAL',11X,5(3X,F7.2),4X,F7.2)
  480 FORMAT ('0',11X,'BASEFLOW',65X,F7.2)
  481 FORMAT (' ',11X,'GRDWATER_RECHARGE',56X,F7.2)
  468 FORMAT (' ',14X,'POTENTIAL',7X,5(3X,F7.2),4X,F7.2)
  469 FORMAT (' ',14X,'NET',13X,5(3X,F7.2),4X,F7.2)
  471 FORMAT (' ',14X,'UPPER_ZONE',6X,5(3X,F7.2),4X,F7.2)
  472 FORMAT (' ',14X,'LOWER_ZONE',6X,5(3X,F7.2),4X,F7.2)
  473 FORMAT (' ',14X,'GROUNDWATER',5X,5(3X,F7.2),4X,F7.2)
  474 FORMAT (' ',14X,'INTERCEPTION',4X,5(3X,F7.2),4X,F7.2)
  475 FORMAT (' ',14X,'OVERLAND_FLOW',3X,5(3X,F7.2),4X,F7.2)
  476 FORMAT (' ',14X,'INTERFLOW',7X,5(3X,F7.2),4X,F7.2)
  477 FORMAT ('0',11X,'WATER_BALANCE=',F8.3)
```

```
C
      STOP
      END
C
C
      BLOCK DATA
C
C
C                    BLOCK DATA TO INITIALIZE VARIABLES
C
C
      IMPLICIT  REAL(L)
C
      DIMENSION  RXB(5), RGX(5), RUZB(5), UZSB(5), PERCB(5), RIB(5)
      DIMENSION  ERSN(5), SRER(5), SRGX(5), RESB(5), MNAM(24)
      DIMENSION  SAS(5), SCS(5), SDS(5), SPRP(5), STS(5), ROSB(5)
      DIMENSION  UAS(5), UCS(5), UDS(5), UPRP(5), UPRI(5), UTS(5)
      DIMENSION  ROBTOM(5), ROBTOT(5), INFTOM(5), INFTOT(5), INTF(5)
      DIMENSION  ROITOM(5), ROITOT(5), ERSTOM(5), ERSTOT(5)
      DIMENSION  PRSTOM(5), PRSTOT(5), PROTOM(5), PROTOT(5)
      DIMENSION  UPITOM(5), UPITOT(5), RESB1(5), SSTR(5), USTR(5)
C
      COMMON  PRTOT, ERSNTT, EIMTT, PRTT, IHR
      COMMON  PRTOM, ERSNTM, EIMTM, PRTM, IMIN
      COMMON  RUTOM, NEPTOM, ROSTOM, RITOM, RINTOM, BASTOM, RCHTOM
      COMMON  RUTOT, NEPTOT, ROSTOT, RITOT, RINTOT, BASTOT, RCHTOT
      COMMON  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT
      COMMON  PRSTOM, PRSTOT, PROTOM, PROTOT, UPITOM, UPITOT
      COMMON  RESB, RESB1, ROSB, TWBAL, SRGX, RU, HYMIN, INTF
      COMMON  MNAM, IX, IZ, DAY, IFLAG, COVER, COVMAX
      COMMON  SPROTM, SPRSTM, ERSTOM, ERSTOT, EPTOM, EPTOT, PRNTKE
      COMMON  STS, STST, SAST, SCST, SDST, UTS, UTST, UAST, UCST, UDST
      COMMON  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, HYCAL, DPST, RIB,UNIT
      COMMON  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS, SGW1
      COMMON  A, UZS, LZS, SGW, GWS, KV, K24L, KK24, K24EL, TF, EP
      COMMON  IFS, K3, EPXM, RESS1, RESS, SCEP, SCEP1, SRGXT, SRGXT1
      COMMON  SRER, JRER, KRER, JSER, KSER, ERSN, SRERT
      COMMON  SAS, SCS, SDS, AREA, M, K, FP, CMAX, SSTR, NI, BULKD
      COMMON  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT
      COMMON  UAS, UCS, UDS, USTR, MUZ, FPUZ
      COMMON  UPRP, UPRITM, UPRITT, MMPIN, METOPT, KGPLB
      COMMON  FPLZ, MLZ, LSTR, LAS, LCS, LDS, LPRP
      COMMON  GSTR, GAS, GCS, GDS
      COMMON  APMODE, CADIF, CBDIF, TEMP, WIND, CONCIU
      COMMON  MOLEWT, APFAC, BPFAC, WCFAC
      COMMON  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS
      COMMON  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS, DEGCON
      COMMON  DEGLOM, DEGLOT
```

Appendix C    (continued)

```
C
      INTEGER  PRNTKE, UNIT
C
      REAL  M, K, NI, MUZ, MLZ
      REAL  LZSN, IRC, NN, L, LZS, KV, K24L, KK24, INFIL, INTER
      REAL  IFS, K24EL, K3, NEPTOM, NEPTOT
      REAL  INFTOM, INFTOT, INTF
      REAL  MMPIN, METOPT, KGPLB
C
      DATA  PRTOT, ERSNTT, EIMTT, PRTT/4*0.0/
      DATA  PRTOM, ERSNTM, EIMTM, PRTM/4*0.0/
      DATA  RUTOM, ROSTOM, RITOM, RINTOM, NEPTOM/5*0.0/
      DATA  RUTOT, ROSTOT, RITOT, RINTOT, NEPTOT/5*0.0/
      DATA  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT/30*0.0/
      DATA  PROTOM, PROTOT, PRSTOM, PRSTOT, UPITOM, UPITOT/30*0.0/
      DATA  TWBAL, RESB, SRGX, INTF, ERSTOM, ERSTOT, SDST/27*0.0/
      DATA  RESB1, BASTOM, RCHTOM, BASTOT, RCHTOT/9*0.0/
      DATA  SPROTM, SPRSTM, EPTOM, EPTOT/4*0.0/, PRNTKE/0/
      DATA  STS, STST, SAST, SCST, UTS, UTST, UAST, UCST,UDST/17*0.0/
      DATA  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, DPST/28*0.0/
      DATA  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS/9*0.0/
      DATA  A, UZS, LZS, SGW, GWS, KV, K24L, KK24/8*0.0/
      DATA  IFS, K24EL, K3, EPXM, COVER, COVMAX/6*0.0/
      DATA  ERSN/5*0.0/, SRER/5*0.0/, SRERT/0.0/
      DATA  SAS/5*0.0/, SCS/5*0.0/, SDS/5*0.0/, AREA, M, K/3*0.0/
      DATA  NI, FP, CMAX, SSTR/8*0.0/
      DATA  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT/9*0.0/
      DATA  UAS/5*0.0/, UCS/5*0.0/, UDS/5*0.0/, USTR, MUZ, FPUZ/7*0.0/
      DATA  UPRP/5*0.0/, UPRITT, UPRITM/2*0.0/
      DATA  LSTR, LAS, LCS, LDS, MLZ, LPRP/6*0.0/
      DATA  GSTR, GAS, GCS, GDS, FPLZ/5*0.0/
      DATA  MNAM/' JAN','UARY','FEBR','UARY','  MA','RCH ','  AP',
     *      'RIL ','  MA','Y   ','  JU','NE  ','  JU','LY  ',' AUG',
     *      'UST ','SEPT','MBER',' OCT','OBER','NOVE','MBER','DECE',
     *      'MBER'/
      DATA  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS/6*0.0/
      DATA  MMPIN/25.4/, METOPT/0.9072/, KGPLB/0.4536/
      DATA  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS/6*0.0/
      DATA  DEGLOM, DEGLOT/2*0.0/
C
      END
C
C
      SUBROUTINE LANDS
C
C
C                             HSP LANDS
C
```

Appendix C (continued)

```
C
      IMPLICIT  REAL(L,K)
C
      DIMENSION  RXB(5), RGB(5), RUZB(5), UZSB(5), PERCB(5), RIB(5)
      DIMENSION  ROBTOM(5), ROBTOT(5), INFTOM(5), INFTOT(5), INTF(5)
      DIMENSION  ROITOM(5), ROITOT(5), ERSTOM(5), ERSTOT(5)
      DIMENSION  PRSTOM(5), PRSTOT(5), PROTOM(5), PROTOT(5)
      DIMENSION  UPITOM(5), UPITOT(5), RESB1(5), SSTR(5), USTR(5)
      DIMENSION  ERSN(5), SRER(5), SRGX(5), RESB(5)
      DIMENSION  SAS(5), SCS(5), SDS(5), SPRP(5), STS(5)
      DIMENSION  UAS(5), UCS(5), UDS(5), UPRP(5), UPRI(5), UTS(5)
      DIMENSION  SHRD(5), RXX(5), ROSB(5), DEEPL(5)
      DIMENSION  UZRA(5), RGX(5), RESBMT(5), SRGXMT(5), UZSBMT(5)
      DIMENSION  PRE(5), INFL(5), UZI(5), DPERCB(5)
      DIMENSION  EVDIST(24), ROSINT(5), MNAM(24)
      DIMENSION  ARXB(5), ARGX(5), ADPRCB(5), ARIB(5)
      DIMENSION  AROSB(5), AINTF(5), AROSIT(5)
C
      COMMON  PRTOT, ERSNTT, EIMTT, PRTT, IHR
      COMMON  PRTOM, ERSNTM, EIMTM, PRTM, IMIN
      COMMON  RUTOM, NEPTOM, ROSTOM, RITOM, RINTOM, BASTOM, RCHTOM
      COMMON  RUTOT, NEPTOT, ROSTOT, RITOT, RINTOT, BASTOT, RCHTOT
      COMMON  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT
      COMMON  PRSTOM, PRSTOT, PROTOM, PROTOT, UPITOM, UPITOT
      COMMON  RESB, RESB1, ROSB, TWBAL, SRGX, RU, HYMIN, INTF
      COMMON  MNAM, IX, IZ, DAY, IFLAG, COVER, COVMAX
      COMMON  SPROTM, SPRSTM, ERSTOM, ERSTOT, EPTOM, EPTOT, PRNTKE
      COMMON  STS, STST, SAST, SCST, SDST, UTS, UTST, UAST, UCST, UDST
      COMMON  PR, P3, RXB, RGB, RUZB, UZSB, PERCB, HYCAL, DPST, RIB,UNIT
      COMMON  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS, SGW1
      COMMON  A, UZS, LZS, SGW, GWS, KV, K24L, KK24, K24EL, TF, EP
      COMMON  IFS, K3, EPXM, RESS1, RESS, SCEP, SCEP1, SRGXT, SRGXT1
      COMMON  SRER, JRER, KRER, JSER, KSER, ERSN, SRERT
      COMMON  SAS, SCS, SDS, AREA, M, K, FP, CMAX, SSTR, NI, BULKD
      COMMON  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT
      COMMON  UAS, UCS, UDS, USTR, MUZ, FPUZ
      COMMON  UPRP, UPRITM, UPRITT, MMPIN, METOPT, KGPLB
      COMMON  FPLZ, MLZ, LSTR, LAS, LCS, LDS, LPRP
      COMMON  GSTR, GAS, GCS, GDS
      COMMON  APMODE, CADIF, CBDIF, TEMP, WIND, CONCIU
      COMMON  MOLEWT, APFAC, BPFAC, WCFAC
      COMMON  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS
      COMMON  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS, DEGCON
      COMMON  DEGLOM, DEGLOT
C
      INTEGER  TF, PRNTKE, HYCAL, DAY, UNIT
C
      REAL  INFIL, INTER, NN, INFLT, IRC, INTF, INFL
      REAL  IRC4, ICS, IFS, NEPTOM, NEPTOT
      REAL  INFTOM, INFTOT, QMETRC
      REAL  MMPIN, METOPT, KGPLB
      REAL  UZSMET, LZSMET, SGWMET, SCEPMT, RESSMT
      REAL  TWBLMT, SRGXTM, RESBMT, SRGXMT
C
      DATA  SIMP/0.0/, IHRR/0/
      DATA  PERC, INFLT/0.0,0.0/
      DATA  SBAS/0.0/
      DATA  RG, RIBT/2*0.0/, DPERCB, DPERC/6*0.0/
      DATA  SNET1, SNET, SRCH/3*0.0/, NUMI/0/
      DATA  ROSINT/5*0.0/, REPIN, EPIN1, AETR, KF/4*0.0/
      DATA  EVDIST/6*0.0,0.019,0.041,0.067,0.088,0.102,3*0.11,0.105,
     C      0.095,0.081,0.055,0.017,5*0.0/
      DATA  ARXB, ARGX, ADPRCB, ARIB, ADPST, APR, AEPIN/23*0.0/
      DATA  AROSB, AINTF, AROSIT/15*0.0/
      DATA  ARU, ARUI, AROS, ARGXT, ASNET, ASBAS, ASRCH/7*0.0/
C
C                    ZEROING OF VARIABLES
C
      LZS1 = LZS
      UZS1 = UZS
      IHRR = 1
      NUMI = 0
      DPST = 0.0
C
        PA=1.0-A
        IRC4=IRC**(1.0/96.0)
        LIRC4=1.0-IRC4
       KK4=KK24**(1.0/96.0)
        LKK4= 1.0 - KK4
C
      IF ((24.*60./TIMFAC) .GT. 100.)  GO TO 185
      GO TO 187
 185  LIRC4 = LIRC4/3.0
      LKKR = LKK4/3.0
C
 187  DEC= 0.00982*((NN*L/SQRT(SS))**0.6)
      SRC= 1020.*SQRT(SS)/(NN*L)
C
      RESS = 0.0
      LNRAT=LZS/LZSN
      D3FV=(2.0*INFIL)/(LNRAT*LNRAT)
      D4F= (TIMFAC/60.)*D3FV
      RATIO= INTER*EXP(0.693147*LNRAT)
      IF ((RATIO).LT.(1.0)) RATIO=1.0
      D4RA= D4F*RATIO
      DO 155  III=1,TF
```

Appendix C (continued)

```
C
      LNRAT = LZS/LZSN
      IF (TF .LT. 2)  GO TO 4
      H = TF/24
      NUMI =NUMI + 1
      IF (NUMI .EQ. H)  GO TO 2
      GO TO 4
  2   NUMI = 0
C
  4   RX = 0.0
      SBAS = 0.0
      SRCH = 0.0
      ROS = 0.0
      RU = 0.0
      GWF = 0.0
      RGXT = 0.0
      PERC = 0.0
      INFLT = 0.0
C
C   TIMFAC - TIME INTERVAL IN MINUTES
C   L      - LENGTH OF OVERLAND SLOPE
C   NN     - MANNING'S N FOR OVERLAND SLOPE
C   A      - IMPERVIOUS AREA
C   PA    - PERVIOUS AREA
C
C
C
C
C PR IS INCOMING RAINFALL
C P3 IS RAIN REACHING SURFACE(.00'S INCHES)
C P4 IS TOTAL MOISTURE AVAILABLE( IN.)
C RESS  IS OVERLAND FLOW STORAGE( IN.)
C D4F IS 'B' IN OP. MANUAL
C RATIO IS 'C' IN OP. MANUAL
C EP -  DAILY EVAP ( IN.)
C EPHR - HOURLY EVAP
C EPIN - INTERVAL EVAP
C
C
       IF ((NUMI .EQ. 0).AND.(IMIN .EQ. 0))  GO TO 202
       GO TO 197
  202 IF (TF .LT. 2)  GO TO 200
       IHRR = IHRR + 1
      GO TO 201
  200 IHRR = IHR + 1
  201 IF (IHRR .GT. 24)  IHRR = 24
       EPHR = EVDIST(IHRR)*EP
       IF (EPHR.LE.(0.0001))  EPHR=0.0
      EPIN= EPHR
      EPIN1=EPIN
C
C
C   * * *    INTERCEPTION  FUNC.    * * *
C
C
C EPXM - MAX. INTERCEPTION STORAGE
C SCEP - EXISTING INTER. STORAGE
C EPX  - AVAILABLE INTER. STORAGE
C SIMP - SUM OF IMPERVIOUS RUNOFF
C RUI  - IMPERVIOUS RUNOFF DURING INTERVAL
C
C
C
 197  IF (COVER - 0.0001)  198,198,204
 198  SNET = SNET + SCEP
      SCEP = 0.0
      EPX = 0.0
      GO TO 203
C
C
 204   EPX=EPXM*(COVER/COVMAX)-SCEP
       IF(EPX.LT.(0.0001))  EPX=0.0
       IF (PR-EPX)   205,203,203
  203  P3= PR-EPX
       RU= P3*A
        RUI=RU
       SIMP=SIMP+RU
       SCEP = SCEP+EPX
       GO TO 206
  205  SCEP = SCEP+PR
       P3=0.0
       RU=0.0
       RUI=0.0
C
C
C
C   * * *      INTERCEPTION EVAP      * * *
C
C
 206   IF ((NUMI .EQ. 0).AND.(IMIN .EQ. 0))  GO TO 207
       GO TO 221
C
  207  IF  (SCEP)  221,221,208
  208  IF (SCEP-EPIN)  209,210,210
  209  EPIN = EPIN - SCEP
       SNET = SNET + SCEP
       SCEP = 0.0
       GO TO 221
  210  SCEP=SCEP-EPIN
  220  SNET=SNET+EPIN
       EPIN = 0.0
C
  221  REPIN=0.0
C
C     ***  INFILTRATION FUNC.  ***
C  P4 IS TOTAL MOISTURE IN STORAGE BLOCK
C SHRD(I) = SURFACE DETENTION AND INTERFLOW FROM BLOCK I
C RXX(I) = SURFACE DETENTION FROM BLOCK I
C RGXX(I) = INTERFLOW  COMPONENT FROM BLOCK I
C  RGX(I) = VOLUME TO INTER. DETEN STOR. FROM BLOCK I
C
C
C      BEGINNING OF BLOCK LOOP
C
C
      DO 100 I=1,5
      P4 = P3 + RESB(I)
      RESB1(I) = RESB(I)
      IF ((10.*P4)-(((2.*I)-1)*D4F)) 10,10,15
   10 SHRD(I)=0.0
      GO TO 25
   15 SHRD(I)= (P4-(((2.*I)-1.0)*D4F/10.))
   16 IF ((10.*P4)-(((2.*I)-1.0)*D4RA)) 25,25,30
   25 RXX(I)= 0.0
      GO TO 31
   30 RXX(I)= (P4-(((2.*I)-1.0)*D4RA/10.))
   31 RGXX  = SHRD(I)-RXX(I)
C
C
C   ***  UPPER ZONE FUNCTION ***
C
C PRE(I)  - % SURFACE DETENTION TO OVERLAND FLOW
C UZSB(I) -  UPPER ZONE STORAGE IN EACH BLOCK
C UZS  - TOTAL UPPER ZONE STORAGE
C RUZB(I) - ADDITION TO U.Z. STORAGE DURING INTERVAL
C
      UZRA(I)= UZSB(I)/UZSN
      IF (UZRA(I)-2.0) 7,7,8
   7  UZI(I)= 2.0*ABS((UZRA(I)/2.0)-1.0) +1.0
      PRE(I)= (UZRA(I)/2.0)*((1.0/(1.0+UZI(I)))**UZI(I))
      GO TO 9
   8  UZI(I)= (2.0*ABS(UZRA(I)-2.0))+1.0
      PRE(I)= 1.0-((1.0/(1.0+UZI(I)))**UZI(I))
   9  RXB(I)= RXX(I)* PRE(I)
```

```
        RGX(I)=RGXX*PRE(I)
        RGXX=0.0
        RUZB(I)=SHRD(I)-RGX(I)-RXB(I)
        UZSB(I)=UZSB(I)+RUZB(I)
C
        RIB(I) = P4 - RXB(I)
C
C
C
C   * * *      UPPER ZONE EVAP    * * *
C
C
C REPIN - EVAP POT. FOR L.Z. AND GRDWATER, I.E
C         PORTION NOT SATISFIED FROM U.Z.
C
C
        IF ((NUMI .EQ. 0).AND.(IMIN .EQ. 0))  GO TO 235
        GO TO 290
C
 235    IF (EPIN.LE.(0.0))  GO TO 290
          EFFECT=1.0
          IF(UZRA(I)-2.0)  230,230,240
  240     IF (UZSB(I)-EPIN)  270,270,260
  260     UZSB(I)=UZSB(I)-EPIN
          RUZB(I)= RUZB(I)-EPIN
          SNET=SNET+PA*EPIN*0.20
          GO TO 290
  230     EFFECT= 0.5*UZRA(I)
          IF (EFFECT.LT.(0.02))  EFFECT=0.02
          IF (UZSB(I)-EPIN*EFFECT)  270,270,280
  280     UZSB(I)=UZSB(I) - (EPIN*EFFECT)
          RUZB(I)= RUZB(I)-(EPIN*EFFECT)
          EDIFF= (1.0-EFFECT)*EPIN
          REPIN=REPIN + EDIFF*0.20
          EDIFF=0.0
          SNET= SNET + (PA*EPIN*EFFECT)*0.20
          GO TO 290
  270     EDIFF= EPIN - UZSB(I)
          REPIN= REPIN + EDIFF*0.20
          EDIFF=0.0
          SNET= SNET + PA*UZSB(I)*0.20
          UZSB(I)=0.0
          RUZB(I)=0.0
C
C
C   * * * *    INTERFLOW FUNCTION * * *
C
```

Appendix C (continued)

```
C     SRGX(I) - INTERFLOW DETENTION STORAGE FROM BLOCK I
C     INTF(I) - INTERFLOW LEAVING STORAGE FROM BLOCK I
C     SRGXT - TOTAL INTERFLOW STORAGE
C     RGXT  - TOTAL INTERFLOW LEAVING STORAGE DURING INTERVAL
C
  290   INTF(I) = LIRC4*SRGX(I)
        SRGX(I)=SRGX(I)+(RGX(I)*PA)-INTF(I)
         RU=RU + INTF(I)*0.20
        SRGXT= SRGXT + (RGX(I)*PA-INTF(I))*0.20
        RGXT=RGXT + INTF(I)*0.20
C
C ***    OVERLAND FLOW ROUTING ***
C
C
C RXB(I) = VOLUME TO OVERLAND SURFACE DETENTION FROM BLOCK I
C  ROSB(I) = VOLUME OF OVERLAND FLOW TO STREAM FROM BLOCK I
C  RESB(I) = VOLUME OF OVERLAND Q REMAINING ON SURFACE
C              FROM BLOCK I
C
      F1= RXB(I)-(RESB(I))
      F3= (RESB(I))+ RXB(I)
      IF (RXB(I)-(RESB(I))) 34,34,32
   32 DE= DEC*((F1)**0.6)
      GO TO 35
   34 DE= (F3)/2.0
   35 IF (F3-(2.0*DE)) 38,38,36
   36 DE=(F3)/2.0
   38 IF ((F3)-(.005)) 40,40,42
   40 ROSB(I)= 0.0
      GO TO 43
   42    DUMV=(1.0+0.6*(F3/(2.0*DE))**3.)**1.67
      ROSB(I)=(TIMFAC/60.)*SRC*((F3/2.)**1.67)*DUMV
      IF ((ROSB(I)).GT.(.95*RXB(I))) GO TO 122
      GO TO 43
  122 IF ((RXB(I)).GT.(0.0)) GO TO 121
      GO TO 43
  121  ROSB(I)=(.95)*RXB(I)
   43 RESB(I)= RXB(I)-ROSB(I)
         ROSB(I) = ROSB(I)*PA
        ROSINT(I) = ROSB(I) + INTF(I)
C
C
C
C         * * *  UPPER ZONE DEPLETION * * *
C
C  DEEPL(I) - DIFFERENCE IN UPPER AND LOWER ZONE RATIOS
C  PERCB(I) - UPPER ZONE DEPLETION FROM EACH BLOCK
C  PERC  - TOTAL U.Z. DEPLETION
```

```
C  INFLT  - TOTAL INFILTRATION
C  ROS  - TOTAL OVERLAND FLOW TO THE STREAM FROM ALL BLOCKS
C
         IF ((NUMI .EQ. 0).AND.(IMIN .EQ. 0))  GO TO 44
         PERCB(I) = 0.0
         GO TO 47
C
  44     DEEPL(I)= ((UZSB(I)/UZSN)-(LZS/LZSN))
         IF (DEEPL(I)-.01)   47,47,45
   45     PERCB(I)=0.1*INFIL*UZSN*(DEEPL(I)**3)
          UZSB(I)=UZSB(I)-PERCB(I)
          PERC=PERC+PERCB(I)*0.2
          RUZB(I) = RUZB(I) - PERCB(I)
  47      INFL(I)= P4-SHRD(I)
           INFLT=INFLT + INFL(I)*0.20
      RESS = RESS + RESB(I)*0.2
       UZS= UZS + RUZB(I)*0.20
      ROS = ROS + ROSB(I)*0.2
  100 RX = RX + RXB(I)*0.2
      IF (UZS .LE. 0.0001) UZS=0.0
C
C END OF BLOCK LOOP
C
         RU=RU + ROS
        IF ((RESS).LT.(0.0001))  GO TO 301
        GO TO 302
  301   LZS = LZS + RESS
        RESS = 0.0
        DO 306  IK= 1,5
  306   RESB(IK)= 0.0
  302   IF (SRGXT.LT.(0.0001))  GO TO 303
        GO TO 305
  303   LZS = LZS + SRGXT/PA
        SRGXT = 0.0
          DO 304  IK= 1,5
  304     SRGX(IK)= 0.0
C
C
C    * * * LOWER ZONE AND GROUNDWATER  * * *
C
C  SBAS  - BASE STREAMFLOW
C  SRCH  - SUM OF GRDWATER RECHARGE
C PREL - % OF INFILTRATION AND U.Z. DEPLETION ENTERING L.Z
C  F1A  - GROUNDWATER RECHARGE - IE. PORTION OF INFIL.
C         AND U.Z. DEPLETION ENTERING GRDWATER
C  K24L  - FRACTION OF F1A LOST TO DEEP GRDWATER
C
  305      LZI=1.5*ABS((LZS/LZSN)-1.0)+1.0
```

```
            PREL=(1.0/(1.0+LZI))**LZI
            IF (LZS.LT.LZSN)  PREL=1.0-PREL*LNRAT
            F3= PREL*(INFLT)
            F1A = (1.0-PREL)*INFLT
            IF ((NUMI .EQ. 0).AND.(1MIN .EQ. 0))  GO TO 308
            GO TO 309
  308       F3 = F3 + PREL*PERC
            F1A = F1A + (1.0-PREL)*PERC
  309       LZS= LZS+F3
         F1= F1A*(1.0 - K24L)*PA
         GWF=SGW*LKK4*(1.0 + KV*GWS)
         SBAS= GWF
         SRCH= F1A*K24L*PA
          SGW=SGW - GWF + F1
          GWS=GWS + F1
C
C   * * *       GROUNDWATER EVAP   * * *
C
C
C LOS  - EVAP LOST FROM GROUNDWATER
C
C
         IF (IHR .EQ. 24)  GO TO 307
         GO TO 101
  307    IF (GWS .GT. 0.0001)  GWS = 0.97*GWS
         LOS= SGW*K24EL*REPIN*PA
         SGW=SGW - LOS
         GWS=GWS - LOS
         SNET= SNET + LOS
         REPIN= REPIN - LOS
         IF (GWS.LT.(0.0))  GWS=0.0
C
C  * * *       LOWER ZONE EVAP  * * *
C
C AETR - EVAP LOST FROM L.Z.
C
C
        LNRAT = LZS/LZSN
        IF (REPIN.LT.(0.0001))  GO TO 101
         IF (K3-1.0)   300,310,310
  310    KF=50.0
         GO TO 320
  300    KF=0.25/(1.0-K3)
  320    IF (REPIN - (KF*LNRAT))  330,330,340
  330    AETR= REPIN*(1.0-(REPIN/(2.0*KF*LNRAT)))
         GO TO 350
  340    AETR= 0.5*(KF*LNRAT)
  350   IF (K3.LT.(0.50))  AETR=AETR*(2.0*K3)
        LZS=LZS - AETR
        SNET= SNET + PA*AETR
  101   SNETI = SNET - SNET1
C
C
C
C WBAL - WATER BALANCE IN THE INTERVAL
C TWBAL - ACCUMULATED WATER BALANCE
C
C
  352   WBAL = (LZS-LZS1+UZS-UZS1+RESS-RESS1)*PA+(SNET-SNET1+SGW-SGW1+
     X          SCEP-SCEP1+SRCH+SRGXT-SRGXT1+GWF+RU-PR)
        IF ((WBAL .LE. 0.0001).AND.(WBAL .GE. -0.0001))  WBAL = 0.0
       TWBAL=TWBAL+WBAL
C
      DPS = F1A*PA
      DPST = DPST + DPS
C
C
C                   RESETTING VARIABLES
C
      LZS1=LZS
      UZS1=UZS
      RESS1=RESS
      SCEP1=SCEP
      SRGXT1=SRGXT
      SGW1=SGW
      SNET1=SNET
C
C
C                   ZEROING OF VARIABLES
C
C
C                   PREPARATION OF OUTPUT
C
      ADPST = ADPST + DPST
       ASBAS = ASBAS + SBAS
       ASRCH = ASRCH + SRCH
      APR = APR + PR
         ARU = ARU + RU
         ARUI = ARUI + RUI
         AROS = AROS + ROS
         ARGXT = ARGXT + RGXT
         IF ((NUMI.EQ.0).AND.(IMIN.EQ.0))  GO TO 146
         GO TO 148
  146    AEPIN = AEPIN + EPIN1
         ASNET = ASNET + SNETI
  148 DO 150  I=1,5
          DPERCB(I) = RIB(I) - RGX(I) - RUZB(I) + 2*PERCB(I)
          ARXB(I) = ARXB(I) + RXB(I)
          ARGX(I) = ARGX(I) + RGX(I)
          ADPRCB(I) = ADPRCB(I) + DPERCB(I)
          ARIB(I) = ARIB(I) + RIB(I)
          AROSB(I) = AROSB(I) + ROSB(I)
          AINTF(I) = AINTF(I) + INTF(I)
          AROSIT(I) = AROSIT(I) + ROSINT(I)
  150     CONTINUE
C
  155 CONTINUE
C
      IF (PRNTKE .EQ. 0)  GO TO 180
C
         RX = 0.0
         RG = 0.0
         RIBT = 0.0
         DPERC = 0.0
C
         DO 158  I=1,5
            DPERC = DPERC + ADPRCB(I)*0.2
            RG = RG + ARGX(I)*0.2
            RX = RX + ARXB(I)*0.2
            RIBT = RIBT + ARIB(I)*0.2
  158       CONTINUE
C
C                    CUMULATIVE RECORDS
C
      PRTOM = PRTOM + APR
      EPTOM = EPTOM + AEPIN
      RUTOM = RUTOM + ARU
      ROSTOM = ROSTOM + AROS
      RITOM = RITOM + ARUI
      RINTOM = RINTOM + ARGXT
      NEPTOM = NEPTOM + ASNET
      BASTOM = BASTOM + ASBAS
      RCHTOM = RCHTOM + ASRCH
C
        DO 157  I=1,5
           ROBTOM(I) = ROBTOM(I) + AROSB(I)
           ROBTOT(I) = ROBTOT(I) + AROSB(I)
           INFTOM(I) = INFTOM(I) + AINTF(I)
           INFTOT(I) = INFTOT(I) + AINTF(I)
           ROITOM(I) = ROITOM(I) + AROSIT(I)
  157      ROITOT(I) = ROITOT(I) + AROSIT(I)
```

```
C
      PRTOT = PRTOT + APR
      EPTOT = EPTOT + AEPIN
      RUTOT = RUTOT + ARU
      ROSTOT = ROSTOT + AROS
      RITOT = RITOT + ARUI
      RINTOT =RINTOT + ARGXT
      NEPTOT = NEPTOT + ASNET
      BASTOT = BASTOT + ASBAS
      RCHTOT = RCHTOT + ASRCH
C
      IF (HYCAL)  159, 160, 159
C
C                    OUTPUT FOR HSP LANDS CALIBRATION RUN
C
C
 159  IF (TF .GT. 2)  GO TO 170
      RU = (RU*AREA*43560.)/(TIMFAC*720.)
      IF (RU .LT. HYMIN)  GO TO 170
      QMETRC=RU*.0283
      WRITE (6,379) MNAM(IZ),MNAM(IX),DAY,IHR,IMIN
      WRITE (6,378) RU,QMETRC
      GO TO 170
C
C                    OUTPUT FOR HSP LANDS PRODUCTION RUN  AND SUMMARIES
C
  160 IF (UNIT .EQ. 1) GO TO 161
      WRITE (6,360)
      WRITE (6,361) APR,APR,APR,APR,APR,APR
      WRITE (6,362)
      WRITE (6,363) AROSB,AROS
      WRITE (6,364) AINTF,ARGXT
      WRITE (6,365) ARUI
      WRITE (6,366) AROSIT,ARU
      WRITE (6,380) ASBAS
      WRITE (6,381) ASRCH
      WRITE (6,367)
      WRITE (6,368) AEPIN,AEPIN,AEPIN,AEPIN,AEPIN,AEPIN
      WRITE (6,369) ASNET,ASNET,ASNET,ASNET,ASNET,ASNET
      WRITE (6,370)
      WRITE (6,371) UZSB,UZS
      WRITE (6,372) LZS,LZS,LZS,LZS,LZS,LZS
      WRITE (6,373) SGW,SGW,SGW,SGW,SGW,SGW
      WRITE (6,374) SCEP,SCEP,SCEP,SCEP,SCEP,SCEP
      WRITE (6,375) RESB,RESS
      WRITE (6,376) SRGX,SRGXT
      WRITE (6,377) TWBAL
  161 IF (UNIT .EQ. -1) GO TO 170
C
C  METRIC CONVERSIONS FOR OUTPUT
      APR   =APR*MMPIN
      AROS  =AROS*MMPIN
      ARGXT =ARGXT*MMPIN
      ARUI  =ARUI*MMPIN
      ARU   =ARU*MMPIN
      ASBAS =ASBAS*MMPIN
      ASRCH =ASRCH*MMPIN
      AEPIN =AEPIN*MMPIN
      ASNET =ASNET*MMPIN
      UZSMET=UZS*MMPIN
      LZSMET=LZS*MMPIN
      SGWMET=SGW*MMPIN
      SCEPMT=SCEP*MMPIN
      RESSMT=RESS*MMPIN
      TWBLMT=TWBAL*MMPIN
      SRGXTM=SRGXT*MMPIN
      DO 162 I=1,5
        AROSB(I) =AROSB(I)*MMPIN
        AINTF(I) =AINTF(I)*MMPIN
        AROSIT(I)=AROSIT(I)*MMPIN
        UZSBMT(I)=UZSB(I)*MMPIN
        RESBMT(I)=RESB(I)*MMPIN
        SRGXMT(I)=SRGX(I)*MMPIN
  162 CONTINUE
      WRITE (6,460)
      WRITE (6,461) APR,APR,APR,APR,APR,APR
      WRITE (6,362)
      WRITE (6,463) AROSB,AROS
      WRITE (6,464) AINTF,ARGXT
      WRITE (6,465) ARUI
      WRITE (6,466) AROSIT,ARU
      WRITE (6,480) ASBAS
      WRITE (6,481) ASRCH
      WRITE (6,367)
      WRITE (6,468) AEPIN,AEPIN,AEPIN,AEPIN,AEPIN,AEPIN
      WRITE (6,469) ASNET,ASNET,ASNET,ASNET,ASNET,ASNET
      WRITE (6,370)
      WRITE (6,471) UZSBMT, UZSMET
      WRITE (6,472) LZSMET, LZSMET, LZSMET, LZSMET, LZSMET, LZSMET
      WRITE (6,473) SGWMET, SGWMET, SGWMET, SGWMET, SGWMET, SGWMET
      WRITE (6,474) SCEPMT, SCEPMT, SCEPMT, SCEPMT, SCEPMT, SCEPMT
      WRITE (6,475) RESBMT, RESSMT
      WRITE (6,476) SRGXMT, SRGXT
      WRITE (6,477) TWBLMT
      GO TO 170
```

```
C
C
C                        FORMAT STATEMENTS
C
  360 FORMAT ('0',8X,'WATER, INCHES')
  361 FORMAT ('0',11X,'PRECIPITATION',6X,5(3X,F7.3),4X,F7.3)
  362 FORMAT ('0',11X,'RUNOFF')
  363 FORMAT (' ',14X,'OVERLAND_FLOW',3X,5(3X,F7.3),4X,F7.3)
  364 FORMAT (' ',14X,'INTERFLOW',7X,5(3X,F7.3),4X,F7.3)
  365 FORMAT (' ',14X,'IMPERVIOUS',55X,5X,F7.3)
  366 FORMAT (' ',14X,'TOTAL',11X,5(3X,F7.3),4X,F7.3)
  367 FORMAT ('0',11X,'EVAPORATION')
  368 FORMAT (' ',14X,'POTENTIAL',7X,5(3X,F7.3),4X,F7.3)
  369 FORMAT (' ',14X,'NET',13X,5(3X,F7.3),4X,F7.3)
  370 FORMAT ('0',11X,'STORAGES')
  371 FORMAT (' ',14X,'UPPER_ZONE',6X,5(3X,F7.3),4X,F7.3)
  372 FORMAT (' ',14X,'LOWER_ZONE',6X,5(3X,F7.3),4X,F7.3)
  373 FORMAT (' ',14X,'GROUNDWATER',5X,5(3X,F7.3),4X,F7.3)
  374 FORMAT (' ',14X,'INTERCEPTION',4X,5(3X,F7.3),4X,F7.3)
  375 FORMAT (' ',14X,'OVERLAND_FLOW',3X,5(3X,F7.3),4X,F7.3)
  376 FORMAT (' ',14X,'INTERFLOW',7X,5(3X,F7.3),4X,F7.3)
  377 FORMAT ('0',11X,'WATER_BALANCE=',F8.4)
  378 FORMAT ('+',25X,F5.1,3X,F5.3)
  379 FORMAT (2X,A4,A4,2X,I2,2X,I2,':',I2)
  380 FORMAT ('0',11X,'BASE_FLOW',64X,F7.3)
  381 FORMAT (' ',11X,'GRDWATER_RECHARGE',56X,F7.3)
  460 FORMAT ('0',8X,'WATER, MILLIMETERS')
  461 FORMAT ('0',11X,'PRECIPITATION',6X,5(3X,F7.2),4X,F7.2)
  463 FORMAT (' ',14X,'OVERLAND_FLOW',3X,5(3X,F7.2),4X,F7.2)
  464 FORMAT (' ',14X,'INTERFLOW',7X,5(3X,F7.2),4X,F7.2)
  465 FORMAT (' ',14X,'IMPERVIOUS',60X,F7.2)
  466 FORMAT (' ',14X,'TOTAL',11X,5(3X,F7.2),4X,F7.2)
  480 FORMAT ('0',11X,'BASEFLOW',65X,F7.2)
  481 FORMAT (' ',11X,'GRDWATER_RECHARGE',56X,F7.2)
  468 FORMAT (' ',14X,'POTENTIAL',7X,5(3X,F7.2),4X,F7.2)
  469 FORMAT (' ',14X,'NET',13X,5(3X,F7.2),4X,F7.2)
  471 FORMAT (' ',14X,'UPPER_ZONE',6X,5(3X,F7.2),4X,F7.2)
  472 FORMAT (' ',14X,'LOWER_ZONE',6X,5(3X,F7.2),4X,F7.2)
  473 FORMAT (' ',14X,'GROUNDWATER',5X,5(3X,F7.2),4X,F7.2)
  474 FORMAT (' ',14X,'INTERCEPTION',4X,5(3X,F7.2),4X,F7.2)
  475 FORMAT (' ', 14X,'OVERLAND_FLOW',3X,5(3X,F7.2),4X,F7.2)
  476 FORMAT (' ',14X,'INTERFLOW',7X,5(3X,F7.2),4X,F7.2)
  477 FORMAT ('0',11X,'WATER_BALANCE=',F8.3)
C
  170 APR = 0.0
      ADPST = 0.0
      AEPIN = 0.0
      ARU = 0.0
      ARUI = 0.0
      AROS = 0.0
      ARGXT = 0.0
      ASNET = 0.0
      ASBAS = 0.0
      ASRCH = 0.0
      DO 172  I=1,5
         ARXB(I) = 0.0
         ARGX(I) = 0.0
         ADPRCB(I) = 0.0
         ARIB(I) = 0.0
         AROSB(I) = 0.0
         AINTF(I) = 0.0
         AROSIT(I) = 0.0
  172    CONTINUE
C
  180 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE SEDT
C
C
C                          SEDIMENT EROSION MODEL
C
C
      DIMENSION  RXB(5), RGX(5), RUZB(5), UZSB(5), PERCB(5), RIB(5)
      DIMENSION  ERSN(5), SRER(5), SRGX(5), RESB(5), MNAM(24)
      DIMENSION  ROBTOM(5), ROBTOT(5), INFTOM(5), INFTOT(5), INTF(5)
      DIMENSION  ROITOM(5), ROITOT(5), ERSTOM(5), ERSTOT(5)
      DIMENSION  PRSTOM(5), PRSTOT(5), PROTOM(5), PROTOT(5)
      DIMENSION  UPITOM(5), UPITOT(5), RESB1(5), SSTR(5), USTR(5)
      DIMENSION  SAS(5), SCS(5), SDS(5), SPRP(5), STS(5)
      DIMENSION  UAS(5), UCS(5), UDS(5), UPRP(5), UPRI(5), UTS(5)
      DIMENSION  AERSN(5), ROSB(5), AERSNM(5), SRERMT(5)
C
      COMMON  PRTOT, ERSNTT, EIMTT, PRTT, IHR
      COMMON  PRTOM, ERSNTM, EIMTM, PRTM, IMIN
      COMMON  RUTOM, NEPTOM, ROSTOM, RITOM, RINTOM, BASTOM, RCHTOM
      COMMON  RUTOT, NEPTOT, ROSTOT, RITOT, RINTOT, BASTOT, RCHTOT
      COMMON  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT
      COMMON  PRSTOM, PRSTOT, PROTOM, PROTOT, UPITOM, UPITOT
      COMMON  RESB, RESB1, ROSB, TWBAL, SRGX, RU, HYMIN, INTF
      COMMON  MNAM, IX, IZ, DAY, IFLAG, COVER, COVMAX
      COMMON  SPROTM, SPRSTM, ERSTOM, ERSTOT, EPTOM, EPTOT, PRNTKE
      COMMON  STS, STST, SAST, SCST, SDST, UTS, UTST, UAST, UCST, UDST
      COMMON  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, HYCAL, DPST, RIB,UNIT
      COMMON  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS, SGW1
      COMMON  A, UZS, LZS, SGW, GWS, KV, K24L, KK24, K24EL, TF, EP
      COMMON  IFS, K3, EPXM, RESS1, RESS, SCEP, SCEP1, SRGXT, SRGXT1
      COMMON  SRER, JRER, KRER, JSER, KSER, ERSN, SRERT
      COMMON  SAS, SCS, SDS, AREA, M, K, FP, CMAX, SSTR, NI, BULKD
      COMMON  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT
      COMMON  UAS, UCS, UDS, USTR, MUZ, FPUZ
      COMMON  UPRP, UPRITM, UPRITT, MMPIN, METOPT  KGPLB
      COMMON  FPLZ, MLZ, LSTR, LAS, LCS, LDS, LPRP
      COMMON  GSTR, GAS, GCS, GDS
      COMMON  APMODE, CADIF, CBDIF, TEMP, WIND, CONCIU
      COMMON  MOLEWT, APFAC, BPFAC, WCFAC
      COMMON  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS
      COMMON  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS, DEGCON
      COMMON  DEGLOM, DEGLOT
C
      INTEGER  PRNTKE, HYCAL, UNIT
C
      REAL JRER, KRER, JSER, KSER, A
      REAL  ERSNTT, SRRTMT, EIMMET
      REAL  MMPIN, METOPT, KGPLB
C
      DATA  ERSNT/0.0/, AERSN, AEIM/6*0.0/
C
C                   ZEROING OF VARIABLES
C
      SRERT = 0.0
      ERSNT = 0.0
      AR = 0.2*AREA
C
C                   SOIL EROSION LOOP
C
      DO 4452 I=1,5
         RER = (1.0 - COVER)*KRER*PR**JRER
            SRER(I) = SRER(I) + RER*AR
         EIM = A*RER*AREA
         IF (ROSB(I)+RESB(I)) 4442, 4442, 4444
C
 4442       ERSN(I) = 0.0
            SER = 0.
            GO TO 4446
C
 4444       SER = KSER*SRER(I)*(ROSB(I)+RESB(I))**JSER
            IF ((SER*AR) .GT. SRER(I)) SER = SRER(I)/AR
            ERSN(I) = (SER)*AR*(ROSB(I)/(ROSB(I)+RESB(I)))
            SRER(I) = SRER(I) - ERSN(I)
            IF (SRER(I) .LT. 0.) SRER(I) = 0.
```

```
C
 4446    AERSN(I) = AERSN(I) + ERSN(I)  + EIM*0.2
 4452    CONTINUE
C
      AEIM = AEIM + EIM
C
      IF (PRNTKE .EQ. 0)  GO TO 4490
C
         DO 4456  I=1,5
            ERSNT = ERSNT + AERSN(I)
            SRERT = SRERT + SRER(I)
            ERSTOM(I) = ERSTOM(I) + AERSN(I)
            ERSTOT(I) = ERSTOT(I) + AERSN(I)
 4456       CONTINUE
C
C                    CUMULATIVE RECORDS
C
      ERSNTM = ERSNTM + ERSNT
      EIMTM = EIMTM + AEIM
C
      ERSNTT = ERSNTT + ERSNT
      EIMTT = EIMTT + AEIM
C
        ERSNTP = 0.0
        ERSNTK = 0.0
        ERSNCE = 0.0
        ERSNCM = 0.0
C
       IF (HYCAL .EQ. 0)  GO TO 4460
       IF (RU .LT. HYMIN)  GO TO 4487
C
C   CONVERSION OF SEDIMENT LOSS TO LBS., KGS., AND GM/L FOR OUTPUT
C
       ERSNTP = ERSNT*2000.
       ERSNTK = ERSNTP*.454
       ERSNCM = ERSNTP*454./(RU*TIMFAC*60.*28.32)
       WRITE (6,4484) ERSNTP, ERSNTK, ERSNCM
       GO TO 4487
C
C
C                      PRINTING OF OUTPUT
C
 4460 IF (UNIT .EQ. 1) GO TO 4462
      WRITE (6,4480)
      WRITE (6,4481)  (AERSN(I), I=1,5), ERSNT
      WRITE (6,4482)  (SRER(I), I=1,5), SRERT
      WRITE (6,4483)  EIM
 4462 IF (UNIT .EQ. -1) GO TO 4487
      ERSNTT=ERSNT*METOPT
      SRRTMT=SRERT*METOPT
      EIMMET=EIM*METOPT
      DO 4461 I=1,5
        AERSNM(I)=AERSN(I)*METOPT
        SRERMT(I)=SRER(I)*METOPT
 4461 CONTINUE
      WRITE (6,4485)
      WRITE (6,4481) AERSNM, ERSNTT
      WRITE (6,4482) SRERMT, SRRTMT
      WRITE (6,4483) EIMMET
C
C                       FORMAT STATEMENTS
C
 4480 FORMAT ('0',8X,'SEDIMENT, TONS')
 4481 FORMAT (' ',11X,'ERODED SEDIMENT',4X,5(3X,F7.3),4X,F7.3)
 4482 FORMAT (' ',11X,'FINES DEPOSIT',6X,5(3X,F7.3),4X,F7.3)
 4483 FORMAT (' ',11X,'IMPERVIOUS EROSION',55X,F7.3)
 4484 FORMAT ('+',40X,3(3X,F7.2))
 4485 FORMAT ('0',8X,'SEDIMENT, TONNES')
C
 4487 AEIM = 0.0
      DO 4489  I=1,5
         AERSN(I) = 0.0
 4489    CONTINUE
C
 4490 CONTINUE
C
      RETURN
      END
C
C
      SUBROUTINE ADSRB1
C
C
C                               SURFACE SOLUTION ADSORPTION MODEL
C
C
      DIMENSION  RXB(5), RGX(5), RUZB(5), UZSB(5), PERCB(5), RIB(5)
      DIMENSION  ERSN(5), SRER(5), SRGX(5), RESB(5), MNAM(24)
      DIMENSION  ROBTOM(5), ROBTOT(5), INFTOM(5), INFTOT(5), INTF(5)
      DIMENSION  ROITOM(5), ROITOT(5), ERSTOM(5), ERSTOT(5)
      DIMENSION  PRSTOM(5), PRSTOT(5), PROTOM(5), PROTOT(5)
      DIMENSION  UPITOM(5), UPITOT(5), RESB1(5), SSTR(5), USTR(5)
      DIMENSION  SAS(5), SCS(5), SDS(5), SPRP(5), STS(5), ROSB(5)
      DIMENSION  UAS(5), UCS(5), UDS(5), UPRP(5), UPRI(5), UTS(5)
      DIMENSION  SAPS(5), SCPS(5), SPRS(5), SPRO(5)
      DIMENSION  SPR(5), SPS(5), SCSC(5), SASC(5), SDSC(5),SPOFS(5)
      DIMENSION  ASPR(5), ASPRS(5), ASPRO(5), ASPRP(5)
      DIMENSION  STSMET(5), SASMET(5), SCSMET(5), SDSMET(5)
C
      COMMON  PRTOT, ERSNTT, EIMTT, PRTT, IHR
      COMMON  PRTOM, ERSNTM, EIMTM, PRTM, IMIN
      COMMON  RUTOM, NEPTOM, ROSTOM, RITOM, RINTOM, BASTOM, RCHTOM
      COMMON  RUTOT, NEPTOT, ROSTOT, RITOT, RINTOT, BASTOT, RCHTOT
      COMMON  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT
      COMMON  PRSTOM, PRSTOT, PROTOM, PROTOT, UPITOM, UPITOT
      COMMON  RESB, RESB1, ROSB, TWBAL, SRGX, RU, HYMIN, INTF
      COMMON  MNAM, IX, IZ, DAY, IFLAG, COVER, COVMAX
      COMMON  SPROTM, SPRSTM, ERSTOM, ERSTOT, EPTOM, EPTOT, PRNTKE
      COMMON  STS, STST, SAST, SCST, SDST, UTS, UTST, UAST, UCST, UDST
      COMMON  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, HYCAL, DPST, RIB,UNIT
      COMMON  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS, SGW1
      COMMON  A, UZS, LZS, SGW, GWS, KV, K24L, KK24, K24EL, TF, EP
      COMMON  IFS, K3, EPXM, RESS1, RESS, SCEP, SCEP1, SRGXT, SRGXT1
      COMMON  SRER, JRER, KRER, JSER, KSER, ERSN, SRERT
      COMMON  SAS, SCS, SDS, AREA, M, K, FP, CMAX, SSTR, NI, BULKD
      COMMON  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT
      COMMON  UAS, UCS, UDS, USTR, MUZ, FPUZ
      COMMON  UPRP, UPRITM, UPRITT, MMPIN, METOPT, KGPLB
      COMMON  FPLZ, MLZ, LSTR, LAS, LCS, LDS, LPRP
      COMMON  GSTR, GAS, GCS, GDS
      COMMON  APMODE, CADIF, CBDIF, TEMP, WIND, CONCIU
      COMMON  MOLEWT, APFAC, BPFAC, WCFAC
      COMMON  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS
      COMMON  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS, DEGCON
      COMMON  DEGLOM, DEGLOT
C
      INTEGER  PRNTKE, HYCAL, UNIT
C
      REAL  M, NI, K, KK, INFW
      REAL  STSTMT, SASTMT, SCSTMT, SDSTMT
      REAL  STSMET, SASMET, SCSMET, SDSMET
      REAL  MMPIN, METOPT, KGPLB
C
      DATA  SPST, SASCT, SCSCT, SPRT, SPRST/5*0.0/
      DATA  SPROT, SPRPT/2*0.0/, INFW/0.0/
      DATA  ASPR, ASPRS, ASPRO, ASPRP/20*0.0/
      DATA  SDSC, SPOFS, SDSCT/11*0.0/
C
C                 ZEROING VARIABLES
C
      STST = 0.0
      SAST = 0.0
      SCST = 0.0
      SDST = 0.0
      ERSNT = 0.0
C
C                  ADSORPTION-SOLUTION LOOP
C
      Z = 1000000.**(NI-1)
      KK = M*K*Z
      DO 5320  I=1,5
         INFW = 0.2*AREA*(P3+RESB1(I))*226512.
         PTOT = SAS(I) + SCS(I) + SDS(I) + SSTR(I)-0.2*(VOLS+DEGS)
         IF (PTOT .LE. 0.0)  PTOT = 0.0
         IF (PTOT-FP)  5310, 5310, 5315
 5310       SAS(I) = PTOT
            SCS(I) = 0.0
            SDS(I) = 0.0
            GO TO 5320
 5315    X = KK*CMAX**NI + FP
         PSLD = PTOT - X - INFW*CMAX
         IF (PSLD .LT. 0.0)  GO TO 5316
            SAS(I) = X
            SCS(I) = PSLD
            SDS(I) = CMAX*INFW
            GO TO 5320
C
 5316       SCS(I) = 0.0
C
            C = CMAX*PTOT/(X + INFW*CMAX)
 5317       X = KK*C**NI + FP
            Q = (PTOT/(X+INFW*C)) - 1.
            IF (ABS(Q) - 0.01)  5319, 5319, 5318
 5318          C = C*PTOT/(X + INFW*C)
               GO TO 5317
C
 5319          IF (INFW .LE. 0.001)  X = PTOT
C
               SDS(I) = (C*INFW)*(PTOT/(X+C*INFW))
               SAS(I) = X*(PTOT/(X+C*INFW))
C
 5320    CONTINUE
C
C                 PESTICIDE REMOVAL LOOP
C
 5325 DO 5330  I=1,5
C
         QS = 2000.*ERSN(I)/M
         IF (QS .GT. 1.0)  QS = 1.0
         SAPS(I) = SAS(I)*QS
         SCPS(I) = SCS(I)*QS
         SPRS(I) = SAPS(I) + SCPS(I)
         SAS(I) = SAS(I) - SAPS(I)
         SCS(I) = SCS(I) - SCPS(I)
C
            SPRO(I) = 0.0
            SPOFS(I) = 0.0
            SPRP(I) = 0.0
            SPR(I) = 0.0
         IF (P3 +RESB1(I))  5327, 5327, 5328
 5327       GO TO 5329
C
 5328       SPRO(I) = SDS(I)*(ROSB(I)/(RESB1(I)+P3))
C
         SPOFS(I) = SDS(I)*(RESB(I)/(RESB1(I)+P3))
         SPRP(I) = SDS(I) - SPRO(I) - SPOFS(I)
         IF (SPRP(I) .LT. 0.0) SPRP(I) = 0.0
         SPR(I) = SPRO(I) + SPRS(I) + SPRP(I)
 5329    SDS(I) = SPOFS(I)
C
         ASPR(I) = ASPR(I) + SPR(I)
         ASPRS(I) = ASPRS(I) + SPRS(I)
         ASPRO(I) = ASPRO(I) + SPRO(I)
         ASPRP(I) = ASPRP(I) + SPRP(I)
C
C
         RESB1(I) = 0.0
C
 5330    CONTINUE
C
      IF (PRNTKE .EQ. 0)  GO TO 5390
C
C                   PREPARATION OF OUTPUT
C
         DO 5335  I=1,5
            SPRT = SPRT +ASPR(I)
            SPROT = SPROT +ASPRO(I)
            SPRST = SPRST +ASPRS(I)
            SPRPT = SPRPT +ASPRP(I)
C
            SAST = SAST + SAS(I)
            SCST = SCST + SCS(I)
            SDST = SDST + SDS(I)
C
            SASC(I) = (SAS(I)/M)*1000000.
            SASCT = SASCT + SASC(I)*0.2
            SCSC(I) = (SCS(I)/M)*1000000.
            SCSCT = SCSCT + SCSC(I)*0.2
            SDSC(I) = (SDS(I)/M)*1000000.
            SDSCT = SDSCT + SDSC(I)*0.2
C
            STS(I) = SAS(I) + SCS(I) + SDS(I)
            SPS(I) = SASC(I) + SCSC(I) + SDSC(I)
            STST = STST + STS(I)
            SPST = SPST + SPS(I)*0.2
C
            ERSNT = ERSNT + ERSN(I)
C
 5335       CONTINUE
C
C                   CUMULATIVE RESULTS
         DO 5337  I= 1,5
            PRSTOM(I) = PRSTOM(I) + ASPRS(I)
            PROTOM(I) = PROTOM(I) + ASPRO(I)
            PROTOT(I) = PROTOT(I) + ASPRO(I)
 5337       PRSTOT(I) = PRSTOT(I) + ASPRS(I)
C
         SPROTM = SPROTM + SPROT
         SPRSTM = SPRSTM + SPRST
C
         SPRTT = SPRTT + SPRT
         SPROTT = SPROTT + SPROT
         SPRPTT = SPRPTT + SPRPT
         SPRSTT = SPRSTT + SPRST
C
         IF (HYCAL .EQ. 0)  GO TO 5340
         IF (HYCAL .EQ. 1)  GO TO 5370
         IF (RU .LT. HYMIN)  GO TO 5370
            SPRTGW = SPROT*454.
            SPRTCW = (SPROT/(RU*TIMFAC*60.*62.43))*1000000.
            SPRTGS = SPRST*454.
         IF (ERSNT .LE. 0.0)  GO TO 5338
            SPRTCS = (SPRST/(ERSNT*2000.))*1000000.
         GO TO 5339
 5338    SPRTCS = 0.0
 5339       WRITE (6,5360) SPRTGW, SPRTCW, SPRTGS, SPRTCS
            GO TO 5370
C                   PRINTING OF OUTPUT
C
 5340 IF (UNIT .EQ. 1) GO TO 5341
      WRITE (6,5350)
      WRITE (6,5351)  STS, STST
      WRITE (6,5352)  SAS, SAST
      WRITE (6,5353)  SCS, SCST
      WRITE (6,5361) SDS, SDST
      WRITE (6,5354)  SPS, SPST
      WRITE (6,5352)  SASC, SASCT
      WRITE (6,5353)  SCSC, SCSCT
      WRITE (6,5361)  SDSC, SDSCT
      WRITE (6,5355)  ASPR, SPRT
      WRITE (6,5356)  ASPRS, SPRST
      WRITE (6,5357)  ASPRO, SPROT
      WRITE (6,5359)  ASPRP, SPRPT
 5341 IF (UNIT .EQ. -1) GO TO 5370
C
C  METRIC CONVERSIONS FOR OUTPUT
      STSTMT=STST*KGPLB
      SASTMT=SAST*KGPLB
      SCSTMT=SCST*KGPLB
      SDSTMT=SDST*KGPLB
      SPRT  =SPRT*KGPLB
      SPRST =SPRST*KGPLB
      SPROT =SPROT*KGPLB
      SPRPT =SPRPT*KGPLB
      DO 5343 I=1,5
        STSMET(I)=STS(I)*KGPLB
        SASMET(I)=SAS(I)*KGPLB
        SCSMET(I)=SCS(I)*KGPLB
        SDSMET(I)=SDS(I)*KGPLB
        ASPR(I)  =ASPR(I)*KGPLB
        ASPRS(I) =ASPRS(I)*KGPLB
        ASPRO(I) =ASPRO(I)*KGPLB
        ASPRP(I) =ASPRP(I)*KGPLB
 5343 CONTINUE
      WRITE (6,5350)
      WRITE (6,5363) STSMET, STSTMT
      WRITE (6,5352) SASMET, SASTMT
      WRITE (6,5353) SCSMET, SCSTMT
      WRITE (6,5361) SDSMET, SDSTMT
      IF (UNIT .EQ. 0) GO TO 5345
      WRITE (6,5354)  SPS, SPST
      WRITE (6,5352)  SASC, SASCT
      WRITE (6,5353)  SCSC, SCSCT
      WRITE (6,5361)  SDSC, SDSCT
 5345 WRITE (6,5374) ASPR,SPRT
      WRITE (6,5356)  ASPRS, SPRST
      WRITE (6,5357)  ASPRO, SPROT
      WRITE (6,5359)  ASPRP, SPRPT
C
C                    FORMAT STATEMENTS
C
 5350 FORMAT  ('0', 5X,'SURFACE LAYER PESTICIDE')
 5351 FORMAT  ('0',8X,'PESTICIDE, LBS',9X,5(3X,F7.3),3X,F8.3)
 5352 FORMAT  (' ',11X,'ADSORBED',12X,5(3X,F7.3),3X,F8.3)
 5353 FORMAT  (' ',11X,'CRYSTALLINE',9X,5(3X,F7.3),3X,F8.3)
 5354 FORMAT  ('0',8X,'PESTICIDE, PPM',9X,5(3X,F7.3),3X,F8.3)
 5355 FORMAT  ('0',8X,'REMOVAL, LBS',11X,5(3X,F7.3),3X,F8.3)
 5356 FORMAT  (' ',11X,'SEDIMENT',12X,5(3X,F7.3),3X,F8.3)
 5357 FORMAT  (' ',11X,'OVERLAND FLOW',7X,5(3X,F7.3),3X,F8.3)
 5359 FORMAT  (' ',11X,'PERCOLATION',9X,5(3X,F7.3),3X,F8.3)
 5360 FORMAT ('+',70X,2(2X,F8.3,3X,F7.3))
 5361 FORMAT (' ',11X,'DISSOLVED',11X,5(3X,F7.3),3X,F8.3)
 5363 FORMAT ('0',8X,'PESTICIDE, KGS',9X,5(3X,F7.3),3X,F8.3)
 5374 FORMAT ('0',8X,'REMOVAL, KGS',11X,5(3X,F7.3),3X,F8.3)
C
C                   ZEROING VARIABLES
C
 5370 DO 5380  I=1,5
         ASPR(I) = 0.0
         ASPRO(I) = 0.0
         ASPRS(I) = 0.0
         ASPRP(I) = 0.0
 5380    CONTINUE
C
 5390 SPST = 0.0
      SASCT = 0.0
      SCSCT = 0.0
      SDSCT = 0.0
      SPRT = 0.0
      SPRST = 0.0
      SPROT = 0.0
      SPRPT = 0.0
C
      DO 5391  I= 1,5
 5391 SSTR(I) = 0.0
C
      RETURN
      END
C
C
      SUBROUTINE ADSRB2
C
C
C                            UPPER ZONE SOLUTION ADSORPTION MODEL
C
C
      DIMENSION  RXB(5), RGX(5), RUZB(5), UZSB(5), PERCB(5), RIB(5)
      DIMENSION  ERSN(5), SRER(5), SRGX(5), RESB(5), MNAM(24)
      DIMENSION  ROBTOM(5), ROBTOT(5), INFTOM(5), INFTOT(5), INTF(5)
      DIMENSION  ROITOM(5), ROITOT(5), ERSTOM(5), ERSTOT(5)
      DIMENSION  PRSTOM(5), PRSTOT(5), PROTOM(5), PROTOT(5)
      DIMENSION  UPITOM(5), UPITOT(5), RESB1(5), SSTR(5), USTR(5)
      DIMENSION  SAS(5), SCS(5), SDS(5), SPRP(5), STS(5), ROSB(5)
      DIMENSION  UAS(5), UCS(5), UDS(5), UPRP(5), UPRI(5), UTS(5)
      DIMENSION  JNFW(5), UDSC(5), UPRIS(5)
      DIMENSION  UPR(5), UPS(5), UCSC(5), UASC(5)
      DIMENSION  AUPR(5), AUPRI(5), AUPRP(5)
      DIMENSION  UTSMET(5), UASMET(5), UCSMET(5), UDSMET(5)
C
      COMMON  PRTOT, ERSNTT, EIMTT, PRTT, IHR
      COMMON  PRTOM, ERSNTM, EIMTM, PRTM, IMIN
      COMMON  RUTOM, NEPTOM, ROSTOM, RITOM, RINTOM, BASTOM, RCHTOM
      COMMON  RUTOT, NEPTOT, ROSTOT, RITOT, RINTOT, BASTOT, RCHTOT
      COMMON  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT
      COMMON  PRSTOM, PRSTOT, PROTOM, PROTOT, UPITOM, UPITOT
      COMMON  RESB, RESB1, ROSB, TWBAL, SRGX, RU, HYMIN, INTF
      COMMON  MNAM, IX, IZ, DAY, IFLAG, COVER, COVMAX
      COMMON  SPROTM, SPRSTM, ERSTOM, ERSTOT, EPTOM, EPTOT, PRNTKE
      COMMON  STS, STST, SAST, SCST, SDST, UTS, UTST, UAST, UCST, UDST
      COMMON  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, HYCAL, DPST, RIB,UNIT
      COMMON  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS, SGW1
      COMMON  A, UZS, LZS, SGW, GWS, KV, K24L, KK24, K24EL, TF, EP
      COMMON  IFS, K3, EPXM, RESS1, RESS, SCEP, SCEP1, SRGXT, SRGXT1
      COMMON  SRER, JRER, KRER, JSER, KSER, ERSN, SRERT
      COMMON  SAS, SCS, SDS, AREA, M, K, FP, CMAX, SSTR, NI, BULKD
      COMMON  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT
      COMMON  UAS, UCS, UDS, USTR, MUZ, FPUZ
      COMMON  UPRP, UPRITM, UPRITT, MMPIN, METOPT, KGPLB
      COMMON  FPLZ, MLZ, LSTR, LAS, LCS, LDS, LPRP
      COMMON  GSTR, GAS, GCS, GDS
      COMMON  APMODE, CADIF, CBDIF, TEMP, WIND, CONCIU
      COMMON  MOLEWT, APFAC, BPFAC, WCFAC
      COMMON  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS
      COMMON  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS, DEGCON
      COMMON  DEGLOM, DEGLOT
C
      INTEGER  PRNTKE, HYCAL, UNIT
C
      REAL  UTSTMT, UASTMT, UCSTMT, UDSTMT
      REAL  UTSMET, UASMET, UCSMET, UDSMET
      REAL  MUZ, NI, K, KK, JNFW, INTF, JJ
      REAL  MMPIN, METOPT, KGPLB
C
      DATA  UPST, UASCT, UCSCT, UPRT, UPRIS/9*0.0/
      DATA  UDSCT, UPRPT/2*0.0/, JNFW/5*0.0/, UPRIT/0.0/
      DATA  AUPR, AUPRI, AUPRP/15*0.0/
C
C                 ZEROING VARIABLES
C
      UTST = 0.0
      UAST = 0.0
      UCST = 0.0
      UDST = 0.0
C
C                   SOLUTION ADSORPTION LOOP
C
      DO 6305  I = 1,5
         JNFW(I) = AREA*(RIB(I)+UZSB(I)-RUZB(I)+(2*PERCB(I)))*45302.4
 6305    CONTINUE
C
      Z = 1000000.**(NI-1)
      KK = MUZ*K*Z
C
      DO 6320  I=1,5
         JJ = JNFW(I)
         PTOT =UAS(I)+UCS(I)+ UDS(I) + SPRP(I) + USTR(I)-0.2*(DEGU+VOLU)
         IF (PTOT .LE. 0.0)  PTOT = 0.0
         C5 = 0.0
         IF (JJ .GT. 0.0)  C5 = UDS(I)/JJ
C
         IF (PTOT-FPUZ)  6310, 6310, 6315
 6310       UAS(I) = PTOT
            UCS(I) = 0.0
            UDS(I) = 0.0
            GO TO 6320
C
 6315    X = KK*CMAX**NI + FPUZ
         PSLD = PTOT - X - JJ*CMAX
         IF (PSLD .LT. 0.0)  GO TO 6316
            UAS(I) = X
            UCS(I) = PSLD
            UDS(I) = CMAX*JJ
            GO TO 6320
C
 6316       UCS(I) = 0.0
C
            C = C5
            IF (C .LE. 0.0)  C = 0.001
 6317       X = KK*C**NI + FPUZ
            Q = (PTOT/(X+JJ*C)) - 1.
            IF (ABS(Q)-0.01)  6319, 6319, 6318
 6318          C = C*PTOT/(X+JJ*C)
               GO TO 6317
C
 6319          IF (JJ .LE. 0.001)  X = PTOT
C
               UDS(I) = (C*JJ)*(PTOT/(X+C*JJ))
               UAS(I) = X*(PTOT/(X+C*JJ))
```

```
C
 6320   CONTINUE
C
C                    PESTICIDE REMOVAL LOOP
C
 6325 DO 6330  I=1,5
C
        IF (JNFW(I) .LE. 0.0001)  GO TO 6327
        QSP = (RIB(I)-RGX(I)-RUZB(I)+(2*PERCB(I)))/JNFW(I)
        IF (QSP .GT. 1.0)  QSP = 1.0
        UPRP(I) = UDS(I)*QSP
        QSI = RGX(I)/JNFW(I)
        IF (QSI .GT. 1.0)  QSI = 1.0
        IF (SRGX(I) .LT. 0.0001)  GO TO 6329
        UPRII = UDS(I)*QSI
        UPRIS(I) = UPRIS(I) + UPRII
        UPRI(I)  = (UPRIS(I))*(INTF(I)/SRGX(I))
        UPRIS(I) = UPRIS(I) - UPRI(I)
        GO TO 6328
 6327   UPRP(I) = 0.0
 6329   UPRI(I) = 0.0
 6328   UDS(I) = UDS(I) - UPRP(I) - UPRI(I)
        IF (UDS(I) .LT. 0.0)  UDS(I) = 0.0
        UPR(I) = UPRP(I) + UPRI(I)
C
        AUPR(I) = AUPR(I) + UPR(I)
        AUPRI(I) = AUPRI(I) + UPRI(I)
        AUPRP(I) = AUPRP(I) + UPRP(I)
C
 6330   CONTINUE
C
      IF (PRNTKE .EQ. 0)  GO TO 6380
C
C                    PREPARATION OF OUTPUT
C
        DO 6335  I=1,5
           UPRT = UPRT + AUPR(I)
           UPRIT = UPRIT + AUPRI(I)
           UPRPT = UPRPT + AUPRP(I)
C
           UAST = UAST + UAS(I)
           UCST = UCST + UCS(I)
           UDST = UDST + UDS(I)
C
           UASC(I) = (UAS(I)/MUZ)*1000000.
           UCSC(I) = (UCS(I)/MUZ)*1000000.
           IF (UZSB(I) .LE. 0.0001)  GO TO 6333
           UDSC(I) = (UDS(I)/(UZSB(I)*AREA*45302.4))*1000000.
```

```
             GO TO 6334
 6333        UDSC(I) = 0.0
 6334        UPS(I) = UASC(I) + UCSC(I) + UDSC(I)
C
             UASCT = UASCT + UASC(I)*0.2
             UCSCT = UCSCT + UCSC(I)*0.2
             UDSCT = UDSCT + UDSC(I)*0.2
             UPST = UPST + UPS(I)*0.2
C
             UTS(I) = UAS(I) + UCS(I) + UDS(I)
             UTST = UTST + UTS(I)
C
 6335        CONTINUE
C
C                    CUMULATIVE RESULTS
C
          DO 6340  I= 1,5
             UPITOM(I) = UPITOM(I) + AUPRI(I)
 6340        UPITOT(I) = UPITOT(I) + AUPRI(I)
      UPRITM = UPRITM + UPRIT
      UPRITT = UPRITT + UPRIT
C
C
           IF (HYCAL .NE. 0)  GO TO 6365
C
C                    PRINTING OF OUTPUT
C
      IF (UNIT .EQ. 1) GO TO 6342
      WRITE (6,6350)
      WRITE (6,6351)  UTS, UTST
      WRITE (6,6352)  UAS, UAST
      WRITE (6,6353)  UCS, UCST
      WRITE (6,6354)  UDS, UDST
      WRITE (6,6355)  UPS, UPST
      WRITE (6,6352)  UASC, UASCT
      WRITE (6,6353)  UCSC, UCSCT
      WRITE (6,6354)  UDSC, UDSCT
      WRITE (6,6357)  AUPR, UPRT
      WRITE (6,6358)  AUPRI, UPRIT
      WRITE (6,6359)  AUPRP, UPRPT
 6342 IF (UNIT .EQ. -1) GO TO 6365
C
C  METRIC CONVERSIONS FOR OUTPUT
      UTSTMT=UTST*KGPLB
      UASTMT=UAST*KGPLB
      UCSTMT=UCST*KGPLB
      UDSTMT=UDST*KGPLB
      UPRT  =UPRT*KGPLB
      UPRIT =UPRIT*KGPLB
      UPRPT =UPRPT*KGPLB
      DO 6344 I=1,5
        UTSMET(I)=UTS(I)*KGPLB
        UASMET(I)=UAS(I)*KGPLB
        UCSMET(I)=UCS(I)*KGPLB
        UDSMET(I)=UDS(I)*KGPLB
        AUPR(I)  =AUPR(I)*KGPLB
        AUPRI(I) =AUPRI(I)*KGPLB
        AUPRP(I) =AUPRP(I)*KGPLB
 6344 CONTINUE
      WRITE (6,6350)
      WRITE (6,6360) UTSMET, UTSTMT
      WRITE (6,6352) UASMET, UASTMT
      WRITE (6,6353) UCSMET, UCSTMT
      WRITE (6,6354) UDSMET, UDSTMT
      IF (UNIT .EQ. 0) GO TO 6345
      WRITE (6,6355)  UPS, UPST
      WRITE (6,6352)  UASC, UASCT
      WRITE (6,6353)  UCSC, UCSCT
      WRITE (6,6354)  UDSC, UDSCT
 6345 WRITE (6,6361) AUPR, UPRT
      WRITE (6,6358)  AUPRI, UPRIT
      WRITE (6,6359)  AUPRP, UPRPT
C
C                   FORMAT STATEMENTS
C
 6350 FORMAT  ('0', 5X,'UPPER ZONE LAYER PESTICIDE')
 6351 FORMAT  ('0',8X,'PESTICIDE, LBS',9X,5(3X,F7.3),3X,F8.3)
 6352 FORMAT  (' ',11X,'ADSORBED',12X,5(3X,F7.3),3X,F8.3)
 6353 FORMAT  (' ',11X,'CRYSTALLINE',9X,5(3X,F7.3),3X,F8.3)
 6354 FORMAT  (' ',11X,'DISSOLVED',11X,5(2X,F8.3),3X,F8.3)
 6355 FORMAT  ('0',8X,'PESTICIDE, PPM',9X,5(3X,F7.3),3X,F8.3)
 6357 FORMAT  ('0',8X,'REMOVAL, LBS',11X,5(3X,F7.3),3X,F8.3)
 6358 FORMAT  (' ',11X,'INTERFLOW',11X,5(3X,F7.3),3X,F8.3)
 6359 FORMAT  (' ',11X,'PERCOLATION',9X,5(3X,F7.3),3X,F8.3)
 6360 FORMAT  ('0',8X,'PESTICIDE, KGS',9X,5(3X,F7.3),3X,F8.3)
 6361 FORMAT  ('0',8X,'REMOVAL, KGS',11X,5(3X,F7.3),3X,F8.3)
C
C                   ZEROING VARIABLES
C
 6365 DO 6370  I=1,5
         AUPR(I) = 0.0
         AUPRI(I) = 0.0
         AUPRP(I) = 0.0
 6370    CONTINUE
```

```
C
 6380 UPST = 0.0
      UASCT = 0.0
      UCSCT = 0.0
      UDSCT = 0.0
      UPRT = 0.0
      UPRPT = 0.0
      UPRIT = 0.0
C
      DO  6381  I= 1,5
 6381 USTR(I) = 0.0
C
      RETURN
      END
C
C
      SUBROUTINE ADSRB3
C
C
C                               LOWER ZONE AND GROUNDWATER
C                               SOLUTION ADSORPTION MODEL
C
C
      IMPLICIT  REAL(L)
C
      DIMENSION  RXB(5), RGX(5), RUZB(5), UZSB(5), PERCB(5), RIB(5)
      DIMENSION  ERSN(5), SRER(5), SRGX(5), RESB(5), MNAM(24)
      DIMENSION  ROBTOM(5), ROBTOT(5), INFTOM(5), INFTOT(5), INTF(5)
      DIMENSION  ROITOM(5), ROITOT(5), ERSTOM(5), ERSTOT(5)
      DIMENSION  PRSTOM(5), PRSTOT(5), PROTOM(5), PROTOT(5)
      DIMENSION  UPITOM(5), UPITOT(5), RESB1(5), SSTR(5), USTR(5)
      DIMENSION  SAS(5), SCS(5), SDS(5), SPRP(5), STS(5), ROSB(5)
      DIMENSION  UAS(5), UCS(5), UDS(5), UPRP(5), UPRI(5), UTS(5)
C
      COMMON  PRTOT, ERSNTT, EIMTT, PRTT, IHR
      COMMON  PRTOM, ERSNTM, EIMTM, PRTM, IMIN
      COMMON  RUTOM, NEPTOM, ROSTOM, RITOM, RINTOM, BASTOM, RCHTOM
      COMMON  RUTOT, NEPTOT, ROSTOT, RITOT, RINTOT, BASTOT, RCHTOT
      COMMON  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT
      COMMON  PRSTOM, PRSTOT, PROTOM, PROTOT, UPITOM, UPITOT
      COMMON  RESB, RESB1, ROSB, TWBAL, SRGX, RU, HYMIN, INTF
      COMMON  MNAM, IX, IZ, DAY, IFLAG, COVER, COVMAX
      COMMON  SPROTM, SPRSTM, ERSTOM, ERSTOT, EPTOM, EPTOT, PRNTKE
      COMMON  STS, STST, SAST, SCST, SDST, UTS, UTST, UAST, UCST, UDST
      COMMON  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, HYCAL, DPST, RIB,UNIT
      COMMON  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS, SGW1
      COMMON  A, UZS, LZS, SGW, GWS, KV, K24L, KK24, K24EL, TF, EP
      COMMON  IFS, K3, EPXM, RESS1, RESS, SCEP, SCEP1, SRGXT, SRGXT1
      COMMON  SRER, JRER, KRER, JSER, KSER, ERSN, SRERT
      COMMON  SAS, SCS, SDS, AREA, M, K, FP, CMAX, SSTR, NI, BULKD
      COMMON  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT
      COMMON  UAS, UCS, UDS, USTR, MUZ, FPUZ
      COMMON  UPRP, UPRITM, UPRITT, MMPIN, METOPT, KGPLB
      COMMON  FPLZ, MLZ, LSTR, LAS, LCS, LDS, LPRP
      COMMON  GSTR, GAS, GCS, GDS
      COMMON  APMODE, CADIF, CBDIF, TEMP, WIND, CONCIU
      COMMON  MOLEWT, APFAC, BPFAC, WCFAC
      COMMON  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS
      COMMON  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS, DEGCON
      COMMON  DEGLOM, DEGLOT
C
      INTEGER  PRNTKE, HYCAL, UNIT
C
      REAL  KNFW, MLZ, K, KK, NI
      REAL  LSTRMT, LASMET, LCSMET, LDSMET
      REAL  GSTRMT, GASMET, GCSMET, GDSMET
      REAL  MMPIN, METOPT, KGPLB
C
      DATA  ALPRP/0.0/
C
C                     SOLUTION ADSORPTION LOOP
C
      LCS = 0.0
      LAS = 0.0
      LDS = 0.0
C
      KNFW = AREA*(LZS+DPST)*226512.
      Z = 1000000.**(NI-1)
      KK = MLZ*K*Z
C
      DO 7305  I=1,5
         LSTR = LSTR + UPRP(I)
 7305    CONTINUE
C
         IF (LSTR .LE. 0.0001)  GO TO 7330
C
      PTOT = LSTR
      C5 = 0.0
      IF (KNFW .GT. 0.0)  C5 = LAS/KNFW
      IF (PTOT-FPLZ)  7310, 7310, 7315
 7310    LAS = PTOT
         LCS = 0
         LDS = 0
         GO TO 7320
```

```
C
 7315 X = KK*CMAX**NI + FPLZ
      PSLD = PTOT - X - KNFW*CMAX
      IF (PSLD .LT. 0.0)  GO TO 7316
         LAS = X
         LCS = PSLD
         LDS = CMAX*KNFW
         GO TO 7320
C
 7316    LCS = 0.0
C
         C = C5
         IF (C .LE. 0.0)  C = 0.001
 7317    X = KK*C**NI + FPLZ
         Q = (PTOT/(X+KNFW*C)) - 1.
         IF (ABS(Q)-0.01)  7319, 7319, 7318
 7318       C = C*PTOT/(X+KNFW*C)
            GO TO 7317
C
 7319 IF (KNFW .LE. 0.001)  X = PTOT
C
        LDS = (C*KNFW)*(PTOT/(X+C*KNFW))
            LAS = X*(PTOT/(X+C*KNFW))
C
 7320    CONTINUE
C
C                   PESTICIDE REMOVAL LOOP
C
      LPRP = LDS*DPST/(DPST+LZS)
      LDS = LDS - LPRP
C
      LSTR = LAS + LCS + LDS
C
      ALPRP = ALPRP + LPRP
C
 7330 IF ((PRNTKE .EQ. 0).OR.(HYCAL .NE. 0))  GO TO 7380
C
C                   PREPARATION OF OUTPUT
C
C
      LASC = (LAS/MLZ)*1000000.
      LCSC = (LCS/MLZ)*1000000.
      LDSC = (LDS/(LZS*AREA*226512.))*1000000.
C
C                   PRINTING OF OUTPUT
C
      IF (UNIT .EQ. 1) GO TO 7340
      WRITE (6,7350)
      WRITE (6,7351)  LSTR
      WRITE (6,7352)  LAS
      WRITE (6,7353)  LCS
      WRITE (6,7354)  LDS
      WRITE (6,7355)
      WRITE (6,7352)  LASC
      WRITE (6,7353)  LCSC
      WRITE (6,7354)  LDSC
      WRITE (6,7357)  ALPRP
      WRITE (6,7359)  ALPRP
 7340 IF (UNIT .EQ. -1) GO TO 7379
C
C  METRIC CONVERSIONS FOR OUTPUT
      LSTRMT=LSTR*KGPLB
      LASMET=LAS*KGPLB
      LCSMET=LCS*KGPLB
      LDSMET=LDS*KGPLB
      ALPRP =ALPRP*KGPLB
      WRITE (6,7350)
      WRITE (6,7360) LSTRMT
      WRITE (6,7352) LASMET
      WRITE (6,7353) LCSMET
      WRITE (6,7354) LDSMET
      IF (UNIT .EQ. 0) GO TO 7345
      WRITE (6,7355)
      WRITE (6,7352)  LASC
      WRITE (6,7353)  LCSC
      WRITE (6,7354)  LDSC
 7345 WRITE (6,7361) ALPRP
      WRITE (6,7359) ALPRP
C
C                    FORMAT STATEMENTS
C
 7350 FORMAT  ('0', 5X,'LOWER ZONE LAYER PESTICIDE')
 7351 FORMAT  ('0',8X,'PESTICIDE, LBS',62X,F8.3)
 7352 FORMAT  (' ',11X,'ADSORBED',65X,F8.3)
 7353 FORMAT  (' ',11X,'CRYSTALLINE',62X,F8.3)
 7354 FORMAT  (' ',11X,'DISSOLVED',64X,F8.3)
 7355 FORMAT  ('0',8X,'PESTICIDE, PPM',62X,F8.3)
 7357 FORMAT  ('0',8X,'REMOVAL, LBS',64X,F8.3)
 7359 FORMAT  (' ',11X,'PERCOLATION',62X,F8.3)
 7360 FORMAT  ('0',8X,'PESTICIDE, KGS',62X,F8.3)
 7361 FORMAT  ('0',8X,'REMOVAL, KGS',64X,F8.3)
C
C                    ZEROING OF VARIABLES
C
 7379 ALPRP = 0.0
```

Appendix C    (continued)

```
C
 7380 CONTINUE
C
C
C                                GROUNDWATER ADSORPTION MODEL
C
C
      GSTR = GSTR + LPRP
      IF (FPLZ .GT. 0.0)  GO TO 7520
         GAS = 0.0
         GDS = GSTR
         GCS = 0.0
C
 7520    GAS = GSTR
         GCS = 0.0
         GDS = 0.0
C
      IF ((PRNTKE .EQ. 0).OR.(HYCAL .NE. 0))  GO TO 7580
C
C                  PRINTING OF OUTPUT
C
      IF (UNIT .EQ. 1) GO TO 7530
      WRITE (6,7550)
      WRITE (6,7551)  GSTR
      WRITE (6,7552)  GAS
      WRITE (6,7553)  GCS
      WRITE (6,7554)  GDS
 7530 IF (UNIT .EQ. -1) GO TO 7580
C
C  METRIC CONVERSIONS FOR OUTPUT
      GSTRMT=GSTR*KGPLB
      GASMET=GAS*KGPLB
      GCSMET=GCS*KGPLB
      GDSMET=GDS*KGPLB
      WRITE (6,7550)
      WRITE (6,7555) GSTRMT
      WRITE (6,7552) GASMET
      WRITE (6,7553) GCSMET
      WRITE (6,7554) GDSMET
C
C                  FORMAT STATEMENTS
C
 7550 FORMAT  ('0',5X,'GROUNDWATER LAYER PESTICIDE')
 7551 FORMAT  ('0',8X,'PESTICIDE, LBS',62X,F8.3)
 7552 FORMAT  (' ',11X,'ADSORBED',65X,F8.3)
 7553 FORMAT  (' ',11X,'CRYSTALLINE',62X,F8.3)
 7554 FORMAT  (' ',11X,'DISSOLVED',64X,F8.3)
 7555 FORMAT ('0',8X,'PESTICIDE, KGS',62X,F8.3)
```

```
C
 7580 CONTINUE
C
      RETURN
      END
C
C
                  SUBROUTINE VOLDEG
C
C
C                     VOLATILIZATION-DEGRADATION MODEL
C
C
C
C              PESTICIDE VOLATILIZATION
C
C  DIFC - DIFFUSION COEFFICIENT (MM2/WK) AT TEMPERATURE
C          TDIFC (C DEGREES)
C  CONCIU - INITIAL PEST. CONC. IN U.Z. IN G/CC
C  BULKD - BULK DENSITY OF SOIL IN G/CC
C  AREA - WATERSHED AREA IN ACRES
C  EVC - EQUIL. VAPOR PRES.  IN MICROGRAMS/CC
C  MOLEWT - MOLECULAR WEIGHT
C  WIND - WIND IN MI/DAY
C  WCFAC - WIND CALIBRATION CONSTANT
C  APMODE - APPLICATION MODE - 0=SURFACE, 1=SOIL
C  PRES - PRESSURE IN MM OF HG
C  APFAC - CONSTANT FOR PRES-TEMP ADJUSTMENT
C  BPFAC - CONSTANT FOR PRES-TEMP ADJUSTMENT
C
      DIMENSION  RXB(5), RGX(5), RUZB(5), UZSB(5), PERCB(5), RIB(5)
      DIMENSION  ERSN(5), SRER(5), SRGX(5), RESB(5), MNAM(24)
      DIMENSION  ROBTOM(5), ROBTOT(5), INFTOM(5), INFTOT(5), INTF(5)
      DIMENSION  ROITOM(5), ROITOT(5), ERSTOM(5), ERSTOT(5)
      DIMENSION  PRSTOM(5), PRSTOT(5), PROTOM(5), PROTOT(5)
      DIMENSION  UPITOM(5), UPITOT(5), RESB1(5), SSTR(5), USTR(5)
      DIMENSION  SAS(5), SCS(5), SDS(5), SPRP(5), STS(5)
      DIMENSION  UAS(5), UCS(5), UDS(5), UPRP(5), UPRI(5), UTS(5)
      DIMENSION  AERSN(5), ROSB(5)
C
      COMMON  PRTOT, ERSNTT, EIMTT, PRTT, IHR
      COMMON  PRTOM, ERSNTM, EIMTM, PRTM, IMIN
      COMMON  RUTOM, NEPTOM, ROSTOM, RITOM, RINTOM, BASTOM, RCHTOM
      COMMON  RUTOT, NEPTOT, ROSTOT, RITOT, RINTOT, BASTOT, RCHTOT
      COMMON  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT
      COMMON  PRSTOM, PRSTOT, PROTOM, PROTOT, UPITOM, UPITOT
      COMMON  RESB, RESB1, ROSB, TWBAL, SRGX, RU, HYMIN, INTF
      COMMON  MNAM, IX, IZ, DAY, IFLAG, COVER, COVMAX
      COMMON  SPROTM, SPRSTM, ERSTOM, ERSTOT, EPTOM, EPTOT, PRNTKE
      COMMON  STS, STST, SAST, SCST, SDST, UTS, UTST, UAST, UCST, UDST
      COMMON  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, HYCAL, DPST, RIB,UNIT
      COMMON  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC, NN, L, SS, SGW1
      COMMON  A, UZS, LZS, SGW, GWS, KV, K24L, KK24, K24EL, TF, EP
      COMMON  IFS, K3, EPXM, RESS1, RESS, SCEP, SCEP1, SRGXT, SRGXT1
      COMMON  SRER, JRER, KRER, JSER, KSER, ERSN, SRERT
      COMMON  SAS, SCS, SDS, AREA, M, K, FP, CMAX, SSTR, NI, BULKD
      COMMON  SPRP, SPROTT, SPRPTT, SPRTT, SPRSTT
      COMMON  UAS, UCS, UDS, USTR, MUZ, FPUZ
      COMMON  UPRP, UPRITM, UPRITT, MMPIN, METOPT, KGPLB
      COMMON  FPLZ, MLZ, LSTR, LAS, LCS, LDS, LPRP
      COMMON  GSTR, GAS, GCS, GDS
      COMMON  APMODE, CADIF, CBDIF, TEMP, WIND, CONCIU
      COMMON  MOLEWT, APFAC, BPFAC, WCFAC
      COMMON  VOLSOM, VOLSOT, VOLUOM, VOLUOT, VOLU, VOLS
      COMMON  DEGSOM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS, DEGCON
      COMMON  DEGLOM, DEGLOT
C
C
       REAL KFAC, MOLEWT, LSTR
       REAL  TVOLMT, VOLSMT, VOLUMT
       REAL  MMPIN, METOPT, KGPLB
       INTEGER APMODE, PRNTKE, HYCAL , UNIT
C
C
       DATA TVOL, TFLUX/2*0.0/, DEGL/0.0/
C
C
C
C               SOIL INCORPORATED PESTICIDE VOLATILIZATION
C                    AND DEGRADATION
C
       IF (UTST .LE. 0.0)  GO TO 8040
       DEGU = DEGCON*UTST
             IF (APMODE .EQ. 0) GO TO 8022
       IF (CADIF .EQ. 0.0)  GO TO 8022
C
             DIFCI = CADIF*(EXP(CBDIF*TEMP))
             KFAC = (SQRT(DIFCI/2198.))*CONCIU
             IF (IFLAG .EQ. 1)  GO TO 8010
             GO TO 8020
 8010        FLUXI = KFAC*(2.0)
             IFLAG = 0
             GO TO 8025
 8020        FLUXI = (2*((KFAC)**2))/TFLUX
 8025        VOLU = FLUXI*AREA*(40.469)/1000.
              TFLUX = TFLUX + FLUXI
             VOLU = VOLU/.454
```

```
C
 8022         UTST = UTST - VOLU - DEGU
              IF  (UTST)  8026,8027,8029
 8026           VOLU = 0.0
                DEGU = 0.0
 8027           UTST = 0.0
 8029         DO 8030  I =1,5
                 UTS(I) = UTS(I) - 0.2*(VOLU+DEGU)
 8030         IF (UTS(I) .LE. 0.0)  UTS(I) = 0.0
C
C
C
C             SURFACE PESTICIDE VOLATILIZATION AND DEGRADATION
C
 8040 IF (STST .LE. 0.0)  GO TO 8070
      DEGS =DEGCON*STST
       IF ((APFAC .EQ. 0.0).AND.(BPFAC .EQ. 0.0))  GO TO 8042
C
               PRES = 10.**(APFAC-BPFAC/(TEMP+273.))
               EVC =  PRES*MOLEWT*10E6/((TEMP+273.)*62365.6)
               FLUXI = WCFAC*WIND*EVC/SQRT(MOLEWT)
               VOLS = FLUXI*AREA*(40.469/1000.)
               VOLS = VOLS/.454
C
 8042          STST = STST - VOLS - DEGS
               IF  (STST)  8050,8055,8057
 8050              VOLS = 0.0
                   DEGS = 0.0
 8055              STST = 0.0
 8057          DO  8060  I= 1,5
                   STS(I) = STS(I) - 0.2*(VOLS+DEGS)
 8060          IF (STS(I) .LE. 0.0)  STS(I) = 0.0
C
C
C   LOWER ZONE PESTICIDE DEGRADATION
C
 8070 IF (LSTR .LE. 0.0) GO TO 8090
      DEGL = DEGCON*LSTR
      LSTR = LSTR - DEGL
      IF (LSTR) 8076, 8077, 8090
 8076     DEGL = 0.0
 8077     LSTR = 0.0
C
C
 8090        CONTINUE
C
C
```

```
C
C                 CUMULATIVE RESULTS
C
      VOLSOM = VOLSOM + VOLS
      VOLSOT = VOLSOT + VOLS
      VOLUOM = VOLUOM + VOLU
      VOLUOT = VOLUOT + VOLU
      DEGSOM = DEGSOM + DEGS
      DEGSOT = DEGSOT + DEGS
      DEGUOM = DEGUOM + DEGU
      DEGUOT = DEGUOT + DEGU
      DEGLOM = DEGLOM + DEGL
      DEGLOT = DEGLOT + DEGL
C
      TVOL = VOLU + VOLS
      TDEG = DEGS + DEGU + DEGL
C
        IF ((PRNTKE .EQ. 0).OR.(HYCAL .NE. 0))  GO TO 8600
C
      IF (UNIT .EQ. 1) GO TO 8200
         WRITE (6,8500)
         WRITE (6,8501) TVOL
         WRITE (6,8502) VOLS
         WRITE (6,8503) VOLU
         WRITE (6,8505)
         WRITE (6,8501) TDEG
         WRITE (6,8502) DEGS
         WRITE (6,8503) DEGU
         WRITE (6,8507) DEGL
 8200 IF (UNIT .EQ. -1) GO TO 8600
C
C  METRIC CONVERSIONS FOR OUTPUT
      TVOLMT=TVOL*KGPLB
      VOLSMT=VOLS*KGPLB
      VOLUMT=VOLU*KGPLB
      TDEGMT=TDEG*KGPLB
      DEGSMT=DEGS*KGPLB
      DEGUMT=DEGU*KGPLB
      DEGLMT=DEGL*KGPLB
      WRITE (6,8504)
      WRITE (6,8501) TVOLMT
      WRITE (6,8502) VOLSMT
      WRITE (6,8503) VOLUMT
      WRITE (6,8506)
      WRITE (6,8501) TDEGMT
      WRITE (6,8502) DEGSMT
      WRITE (6,8503) DEGUMT
      WRITE (6,8507) DEGLMT
```

Appendix C (continued)

```
C
C
 8500 FORMAT ('0',5X,'PESTICIDE VOLATILIZATION LOSS, LBS.')
 8501 FORMAT (' ',8X,'TOTAL',72X,F7.3)
 8502 FORMAT (' ',8X,'FROM SURFACE',65X,F7.3)
 8503 FORMAT (' ',8X,'FROM UPPER ZONE',62X,F7.3)
 8504 FORMAT ('0',5X,'PESTICIDE VOLATILIZATION LOSS, KGS.')
 8505 FORMAT ('0',5X,'PESTICIDE DEGRADATION LOSS, LBS.')
 8506 FORMAT ('0',5X,'PESTICIDE DEGRADATION LOSS, KGS.')
 8507 FORMAT (' ',8X,'FROM LOWER ZONE',62X,F7.3)
C
 8600 RETURN
      END
/*
//LKED.SYSLMOD DD DSNAME=C510.TONY.PEST10,DISP=(NEW,KEEP),
//             SPACE=(TRK,(15,1,1),RLSE),UNIT=2314,
//             VOL=SER=SYS13
//LKED.SYSIN DD *
    NAME  PEST
/*
```

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